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- (54) **NUCLEIC ACID MOLECULE AND ENCODED PROTEIN ASSOCIATED WITH STEROL SYNTHESIS AND METABOLISM**
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(57) **ABSTRACT**

This invention relates to the field of biotechnology, particularly as it pertains to a nucleic acid molecule encoding a protein associated with sterol and phytosterol synthesis and metabolism. The invention also relates to methods of detection using the nucleic acid molecule, or the encoded protein as a probe or in a microarray.

2 Claims, No Drawings

NUCLEIC ACID MOLECULE AND ENCODED PROTEIN ASSOCIATED WITH STEROL SYNTHESIS AND METABOLISM

This application claims the benefit of provisional application No. 60/142,981 filed on Jul. 12, 1999.

FIELD OF THE INVENTION

This invention relates to the field of biotechnology, particularly as it pertains to the production of sterols in a variety of host systems particularly plants. More specifically, the invention relates to nucleic acid molecules encoding proteins and fragments of proteins associated with sterol and phytosterol metabolism as well as the encoded proteins and fragments of proteins and antibodies capable of binding to them. The invention also relates to methods of using the nucleic acid molecules, fragments of the nucleic acid molecules, proteins, and fragments of proteins. The invention also relates to cells, organisms, particularly plants, or seeds, or progeny of plants, that have been manipulated to contain increased levels or overexpress at least one sterol or phytosterol compound.

BACKGROUND OF THE INVENTION

Sterols are a class of essential, natural compounds required by all eukaryotes to complete their life cycle. The types of sterols produced and predominantly present within each of the phylogenetic kingdoms varies. Plants produce a class of sterols called phytosterols. A phytosterol called sitosterol predominates. In animals, cholesterol is typically the major sterol while in fungi it is ergosterol.

Phytosterols from plants possess a wide spectrum of biological activities in animals and humans. Phytosterols are considered efficacious cholesterol-lowering agents (Pelletier et al., *Annals Nutrit. Metab.* 39:291-295 (1995). The entirety of which is herein incorporated by reference). Lower cholesterol levels are linked to a reduction in the risk to cardiovascular disease. Phytosterols can also block cholesterol absorption in the intestine, which would also lead to lower cholesterol levels. Thus, enhancing the levels of phytosterols in edible plants and seeds, or products derived from these plants and seeds, may lead to food products with increased nutritive or therapeutic value.

In one aspect, this invention provides these desirable plants and seeds as well as methods to produce them. Since, as will be discussed below, the genetic manipulation made possible by this invention involves families of related genes that cross phylogenetic boundaries, the effects are not limited to plants alone.

Biochemistry of Sterol Synthesis

A number of the important sterol biosynthetic enzymes, reactions, and intermediates have been described. Sterol synthesis uses acetyl CoA as the basic carbon building block. Multiple acetyl CoA molecules form the five-carbon isoprene units, hence the name isoprenoid pathway. Enzymatic combination of isoprene units leads to the thirty-carbon squalene molecule, which is the penultimate precursor to sterols.

Throughout plants, animals, and fungus, the reactions proceed as: acetyl CoA → HMGCoA, mevalonate, mevalonate 5 phosphate, mevalonate 5-pyrophosphate, isopentyl diphosphate, 5-pyrophosphatemevalonate, isopentyl pyrophosphate (PIP), dimethylallyl pyrophosphate (DMAPP), PIP+DMAPP, geranyl pyrophosphate+IPP, farnesyl pyrophosphate, 2 farnesyl pyrophosphate, squalene and squalene epoxide

From squalene epoxide, the sterol biosynthesis pathway of plants diverges from that of animals and fungi. In plants, cycloartenol is produced next by cyclization of squalene epoxide. The plant pathway eventually leads to the synthesis of the predominant phytosterol, sitosterol.

Animals go on to produce lanosterol from squalene epoxide, eventually leading to cholesterol, which is the precursor to steroid hormones and bile acids, among other compounds. In fungi, lanosterol leads to the production of the predominant sterol, ergosterol.

An important regulatory control step within the pathway consists of the HMGCoA_Mevalonate step, catalyzed by HMGCoA reductase, and the condensation of 2 farnesyl pyrophosphates → squalene, catalyzed by squalene synthase. An early, reported rate-limiting step, in the pathway is the HMGCoA reductase-catalyzed reaction.

A number of studies have focused on the regulation of HMGCoA reductase, HMGCoA reductase (EC 1.1.1.34) catalyzes the reductive conversion of HMGCoA to mevalonic acid (MVA). This reaction is a reported controlling step in isoprenoid biosynthesis. The enzyme is regulated by feedback mechanisms and by a system of activation kinases and phosphatases (Gray, *Adv. Bot. Res.* 14: 25 (1987); Bach et al., *Lipids*, 26: 637 (1991); Stermer et al., *J. Lipid Res.*, 35: 1133 (1994), all of which are herein incorporated by reference in their entirety).

Another important regulation occurs at the squalene synthase step. Squalene synthase (EC 2.5.1.21) reductively condenses two molecules of FPP in the presence of Mg²⁺ and NADPH to form squalene. The reaction involves a head-to-head condensation and forms a stable intermediate, presqualene diphosphate. The enzyme is subject to regulation similar to that of HMGCoA reductase and acts by balancing the incorporation of FPP into sterols and other compounds.

The sterol pathway of plants diverges from that in animals and fungi after squalene epoxide. In plants, the cyclization of squalene epoxide occurs next, under the regulated control of cycloartenol synthase (EC 5.4.99.8). The cyclization mechanism proceeds from the epoxy end into a chair-boat-chair-boat sequence that is mediated by a transient C-20 carbocationic intermediate. The reported rate-limiting step in plant sterol synthesis occurs in the next step, S-adenosyl-L-methionine:sterol C-24 methyl transferase (EC 2.1.1.41) (SMT_I) catalyzing the transfer of a methyl group from a cofactor, S-adenosyl-L-methionine, to the C-24 center of the sterol side chain. This is the first of two methyl transfer reactions. The second methyl transfer reaction occurs further down in the pathway and has been reported to be catalyzed by SMT_{II}. An isoform enzyme. SMT_{II}, catalyzes the conversion of 24-methylene lophenol to 24-ethylidene lophenol (Fonteneau et al., *Plant Sci Lett* 10:147-155(1977), the entirety of which is herein incorporated by reference). The presence of two distinct SMTs in plants were further confirmed by cloning cDNAs code the enzymes from Arabidopsis (Husselstein et al., *FEBS Lett* 381:87-92(1996), the entirety of which is herein incorporated by reference), soybean (Shi et al., *J Biol Chem* 271: 9384-9389(1996), the entirety of which is herein incorporated by reference), maize (Grebekok et al., *Plant Mol Biol* 34: 891-896(1997), the entirety of which is herein incorporated by reference) and tobacco (Bouvier-Nave et al., *Eur J Biochem* 246: 518-529 (1997); Bouvier-Nave et al., *Eur J Biochem* 256: 88-96 (1998), both of which are herein incorporated by reference in their entirety).

Later in the pathway, a sterol C-14 demethylase catalyzes the demethylation at C-14, removing the methyl group and

creating a double bond. Interestingly, this enzyme also occurs in plants and fungi, but at a different point in the pathway. Sterol C14-demethylation is mediated by a cytochrome P-450 complex. A large family of enzymes utilize the cytochrome P-450 complex. There is, in addition, a family of cytochrome P450 complexes. For example, sterol C-22 desaturase (EC 2.7.3.9) catalyzes the formation of the double bond at C-22 on the side chain. The C-22 desaturase in yeast, which is the final step in the biosynthesis of ergosterol, contains a cytochrome P450 that is distinct from the cytochrome P450 participating in the demethylation reaction. Additional cytochrome P450 enzymes participate in brassinosteroid synthesis (Bishop, *Plant Cell* 8:959-969 (1996), the entirety of which is herein incorporated by reference). Brassinosteroids are steroidal compounds with plant growth regulatory properties, including modulation of cell expansion and photomorphogenesis (Arteca, *Plant Hormones, Physiology, Biochemistry and Molecular Biology* ed. Davies, Kluwer Academic Publishers, Dordrecht, 66 (1995), Yakota, *Trends in Plant Science* 2:137-143 (1997), both of which are herein incorporated by reference in their entirety.

One class of proteins, oxysterol-binding proteins, have been reported in humans and yeast (Jiang et al., *Yeast* 10: 341-353 (1994), the entirety of which is herein incorporated by reference). These proteins have been reported to modulate ergosterol levels in yeast (Jiang et al., *Yeast* 10: 341-353 (1994)). In particular, Jiang et al., reported three genes KES1, HES1 and OSH1, which encode proteins containing an oxysterol-binding region.

Enzyme Inhibitors and Modulators

Self-regulatory and feedback regulatory mechanisms of some of the sterol synthesis enzymes provide opportunities to effect sterol metabolism. For example, the introduction of the feedback inhibitor molecule inhibits enzyme action while the removal of that molecule up-regulates the enzyme. In certain circumstances, non-wild type enzymes can effect normal regulation. These organisms can be generated, for example, by traditional genetic crosses, mutation treatments and through molecular genetics. One example is the over-expression of plant HMGCoA reductase in transgenic plants resulting in a 6-10 fold increase in the total sterol levels (for example, transgenic tobacco plants overproducing phytosterols in Schaller et al., *Plant Physiol.* 109: 761 (1995), the entirety of which is herein incorporated by reference).

A number of compounds have been identified that, at least partially, exert their effects on sterol synthesis. For example, mevlinolic acid and lovastatin are competitive inhibitors of HMGCoA reductase and zaragonic acid is a competitive inhibitor of squalene synthase (Alberts et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 77:3957-61 (1993); Bergstrom et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 90:80-84 (1980), both of which are herein incorporated by reference). Many fungicides and insecticides act by inhibiting enzymes, such as those noted above or the C-14 demethylase enzyme (*Sterol Biosynthesis inhibitors and Anti-feeding Compounds*, Kato et al., Springer-Verlag, New York (1986); *Sterol biosynthesis inhibitors: pharmaceutical and agrochemical aspects*, eds. Berg and Plempel, Ellis Horwood, Chichester, England (1988), both of which are herein incorporated by reference in this entirety).

However, the use of these compounds can have toxic effects that preclude their use in products destined for animal or human consumption. Furthermore, the increase or decrease in sterol levels possible using these compounds is limited. Typically, the changes in levels occur over a wide spectrum of the pathway. New and more effective methods for manipulating sterol synthesis are desired.

The present invention provides a gene, *Hes1*, involved in plant phytosterol production. Expression of HES1 (protein) in organisms such as plants can increase phytosterol biosynthesis. The present invention also provides transgenic organisms expressing a HES1 protein, which can enhance food and feed sources.

SUMMARY OF THE INVENTION

The present invention includes a substantially purified nucleic acid molecule that encodes a protein comprising the amino acid sequence of SEQ ID NO: 622.

The present invention includes a substantially purified nucleic acid molecule that specifically hybridizes to a nucleic acid sequence of SEQ ID NO: 1 or its complement, wherein the nucleic acid molecule encodes a protein comprising the amino acid sequence of SEQ ID NO: 622.

The present invention includes a substantially purified nucleic acid molecule that encodes a protein comprising the amino acid sequence of SEQ ID NO: 623.

The present invention includes a substantially purified nucleic acid molecule that specifically hybridizes to a nucleic acid sequence of SEQ ID NO: 2 or its complement, wherein the nucleic acid molecule encodes a protein comprising the amino acid sequence of SEQ ID NO: 623.

The present invention includes a substantially purified nucleic acid molecule that encodes a protein comprising the amino acid sequence of SEQ ID NO: 624.

The present invention includes a substantially purified nucleic acid molecule that specifically hybridizes to a nucleic acid sequence of SEQ ID NO: 3 or its complement, wherein the nucleic acid molecule encodes a protein comprising the amino acid sequence of SEQ ID NO: 624.

The present invention includes a substantially purified nucleic acid molecule that encodes a protein comprising the amino acid sequence of SEQ ID NO: 625.

The present invention includes a substantially purified nucleic acid molecule that specifically hybridizes to a nucleic acid sequence of SEQ ID NO: 4 or its complement, wherein the nucleic acid molecule encodes a protein comprising the amino acid sequence of SEQ ID NO: 625.

The present invention includes a substantially purified nucleic acid molecule comprising a nucleic acid sequence which encodes a plant HES1 protein.

The present invention includes an antibody capable of specifically binding a protein comprising the amino acid sequence of SEQ ID NO: 622.

The present invention includes an antibody capable of specifically binding a protein comprising the amino acid sequence of SEQ ID NO: 623.

The present invention includes an antibody capable of specifically binding a protein comprising the amino acid sequence of SEQ ID NO: 624.

The present invention includes an antibody capable of specifically binding a protein comprising the amino acid sequence of SEQ ID NO: 625.

The present invention also provides a transformed plant having a nucleic acid molecule which comprises: (A) an exogenous promoter region which functions in a plant cell to cause the production of a mRNA molecule; which is linked to (B) a structural nucleic acid molecule, wherein the structural nucleic acid molecule comprises a nucleic acid sequence encoding a protein having an amino acid sequence selected from the group consisting of SEQ ID NO: 622 through SEQ ID NO: 626 or fragment thereof; which is

linked to (C) a 3' non-translated sequence that functions in the plant cell to cause termination of transcription and addition of polyadenylated ribonucleotides to a 3' end of the mRNA molecule.

The present invention also provides a transformed plant having a nucleic acid molecule which comprises: (A) an exogenous promoter region which functions in a plant cell to cause the production of a mRNA molecule; which is linked to (B) a transcribed nucleic acid molecule with a transcribed strand and a non-transcribed strand, wherein the transcribed strand is complementary to a nucleic acid molecule comprising a nucleic acid sequence selected from the group consisting of SEQ ID NO: 1 through SEQ ID NO: 621 or fragment thereof; which is linked to (C) a 3' non-translated sequence that functions in plant cells to cause termination of transcription and addition of polyadenylated ribonucleotides to a 3' end of the mRNA molecule.

The present invention also provides a method for determining a level or pattern in a plant of a protein in a plant comprising: (A) incubating, under conditions permitting nucleic acid hybridization, a marker nucleic acid molecule, the marker nucleic acid molecule selected from the group of marker nucleic acid molecules which specifically hybridize to a nucleic acid molecule having the nucleic acid sequence of SEQ ID NO: 1 through SEQ ID NO: 621 or complements thereof, with a complementary nucleic acid molecule obtained from the plant cell or plant tissue. Wherein nucleic acid hybridization between the marker nucleic acid molecule and the complementary nucleic acid molecule obtained from the plant permits the detection of an mRNA for the enzyme; (B) permitting hybridization between the marker nucleic acid molecule and the complementary nucleic acid molecule obtained from the plant cell or plant tissue; and (C) detecting the level or pattern of the complementary nucleic acid, wherein the detection of the complementary nucleic acid is predictive of the level or pattern of the protein in the plant.

The present invention also provides a method for determining a level or pattern of a protein in a plant under evaluation which comprises assaying the concentration of a molecule, whose concentration is dependent upon the expression of a gene, the gene specifically hybridizes to a nucleic acid molecule having a nucleic acid sequence selected from the group consisting of SEQ ID NO: 1 through SEQ ID NO: 621 or complements thereof, in comparison to the concentration of that molecule present in a reference plant with a known level or pattern of the protein, wherein the assayed concentration of the molecule is compared to the assayed concentration of the molecule in the reference plant with the known level or pattern of the protein.

The present invention also provides a method for determining a mutation in a plant whose presence is predictive of a mutation affecting a level or pattern of a protein comprising the steps: (A) incubating, under conditions permitting nucleic acid hybridization, a marker nucleic acid, the marker nucleic acid selected from the group of marker nucleic acid molecules which specifically hybridize to a nucleic acid molecule having a nucleic acid sequence selected from the group of SEQ ID NO: 1 through SEQ ID NO: 621 or complements thereof and a complementary nucleic acid molecule obtained from the plant, wherein nucleic acid hybridization between the marker nucleic acid molecule and the complementary nucleic acid molecule obtained from the plant permits the detection of a polymorphism whose presence is predictive of a mutation affecting the level or pattern of the protein in the plant: (B) permitting hybridization between the marker nucleic acid molecule and the complementary nucleic acid molecule obtained from the plant; and

(C) detecting the presence of the polymorphism, wherein the detection of the polymorphism is predictive of the mutation.

The present invention also provides a method of producing a plant containing an overexpressed protein comprising: (A) transforming the plant with a functional nucleic acid molecule, wherein the functional nucleic acid molecule comprises a promoter region, wherein the promoter region is linked to a structural region, wherein the structural region has a nucleic acid sequence selected from group consisting of SEQ ID NO: 1 through SEQ ID NO: 621, wherein the structural region is linked to a 3' non-translated sequence that functions in the plant to cause termination of transcription and addition of polyadenylated ribonucleotides to a 3' end of a mRNA molecule; and wherein the functional nucleic acid molecule results in overexpression of the protein; and (B) growing the transformed plant.

The present invention also provides a method of producing a plant containing an overexpressed protein comprising: (A) transforming the plant with a functional nucleic acid molecule, wherein the functional nucleic acid molecule comprises a promoter region, wherein the promoter region is linked to a structural region, wherein the structural region encodes a protein comprising an amino acid sequence selected from group consisting of SEQ ID NO: 622 through SEQ ID NO: 626, wherein the structural region is linked to a 3' non-translated sequence that functions in the plant to cause termination of transcription and addition of polyadenylated ribonucleotides to a 3' end of a mRNA molecule; and wherein the functional nucleic acid molecule results in overexpression of the protein; and (B) growing the transformed plant.

The present invention also provides a method of producing a plant containing reduced levels of a protein comprising: (A) transforming the plant with a functional nucleic acid molecule, wherein the functional nucleic acid molecule comprises a promoter region, wherein the promoter region is linked to a structural region, wherein the structural region comprises a nucleic acid molecule having a nucleic acid sequence selected from the group consisting of SEQ ID NO: 1 through SEQ ID NO: 621; wherein the structural region is linked to a 3' non-translated sequence that functions in the plant to cause termination of transcription and addition of polyadenylated ribonucleotides to a 3' end of a mRNA molecule and wherein the functional nucleic acid molecule results in co-suppression of the protein, and (B) growing the transformed plant.

The present invention also provides a method of producing a plant containing reduced levels of a protein comprising: (A) transforming the plant with a functional nucleic acid molecule, wherein the functional nucleic acid molecule comprises a promoter region, wherein the promoter region is linked to a structural region, wherein the structural region encodes a protein comprising an amino acid sequence selected from group consisting of SEQ ID NO: 622 through SEQ ID NO: 626; wherein the structural region is linked to a 3' non-translated sequence that functions in the plant to cause termination of transcription and addition of polyadenylated ribonucleotides to a 3' end of a mRNA molecule and wherein the functional nucleic acid molecule results in co-suppression of the protein; and (B) growing the transformed plant.

The present invention also provides a method for reducing expression of a protein in a plant comprising: (A) transforming the plant with a nucleic acid molecule, the nucleic acid molecule having an exogenous promoter region which functions in a plant cell to cause the production of a mRNA

molecule, wherein the exogenous promoter region is linked to a transcribed nucleic acid molecule having a transcribed strand and a non-transcribed strand, wherein the transcribed strand is complementary to a nucleic acid molecule having a nucleic acid sequence selected from the group consisting of SEQ ID NO: 1 through SEQ ID NO: 621 or fragments thereof and the transcribed strand is complementary to an endogenous mRNA molecule; and wherein the transcribed nucleic acid molecule is linked to a 3' non-translated sequence that functions in the plant cell to cause termination of transcription and addition of polyadenylated ribonucleotides to a 3' end of a mRNA molecule; and (B) growing the transformed plant.

The present invention also provides a method for reducing expression of a protein in a plant comprising: (A) transforming the plant with a nucleic acid molecule, the nucleic acid molecule having an exogenous promoter region which functions in a plant cell to cause the production of a mRNA molecule, wherein the exogenous promoter region is linked to a transcribed nucleic acid molecule having a transcribed strand and a non-transcribed strand, wherein the transcribed strand is complementary to a nucleic acid molecule having a nucleic acid encodes a protein comprising an amino acid sequence selected from group consisting of SEQ ID NO: 622 through SEQ ID NO: 626 or fragments thereof and the transcribed strand is complementary to an endogenous mRNA molecule, and wherein the transcribed nucleic acid molecule is linked to a 3' non-translated sequence that functions in the plant cell to cause termination of transcription and addition of polyadenylated ribonucleotides to a 3' end of a mRNA molecule; and (B) growing the transformed plant.

The present invention also provides a method of determining an association between a polymorphism and a plant trait comprising: (A) hybridizing a nucleic acid molecule specific for the polymorphism to genetic material of a plant, wherein the nucleic acid molecule has a nucleic acid sequence selected from the group consisting of SEQ ID NO: 1 through SEQ ID NO: 621 or complements thereof or fragment of either; and (B) calculating the degree of association between the polymorphism and the plant trait.

The present invention also provides a method of isolating a nucleic acid that encodes a protein or fragment thereof comprising: (A) incubating under conditions permitting nucleic acid hybridization, a first nucleic acid molecule comprising a nucleic acid sequence selected from the group consisting of SEQ ID NO: 1 through SEQ ID NO: 621 or complements thereof or fragment of either with a complementary second nucleic acid molecule obtained from a plant; (B) permitting hybridization between the first nucleic acid molecule and the second nucleic acid molecule obtained from the plant; and (C) isolating the second nucleic acid molecule.

The present invention also provides a method for producing a protein or fragment thereof in an organism comprising introducing a vector comprising a nucleic acid of the present invention and expressing the protein or fragment.

DETAILED DESCRIPTION OF THE INVENTION

One skilled in the art can refer to general reference texts for detailed descriptions of known techniques discussed herein or equivalent techniques. These texts include *Current Protocols in Molecular Biology* Ausubel, et al., eds., John Wiley & Sons, N.Y. (1989), and supplements through September (1998), *Molecular Cloning, A Laboratory Manual*

(Sambrook et al., 2nd Ed., Cold Spring Harbor Press, Cold Spring Harbor, N.Y. (1989), for example, each of which are specifically incorporated by reference in their entirety). These texts can also be referred to in making or using an aspect of the invention.

The agents of the invention will preferably be "biologically active" with respect to either a structural attribute, such as the capacity of a nucleic acid to hybridize to another nucleic acid molecule, or the ability of a protein to be bound by an antibody (or to compete with another molecule for such binding). Alternatively, such an attribute may be catalytic and thus involve the capacity of the agent to mediate a chemical reaction or response.

The term "substantially purified", as used herein, refers to a molecule separated from substantially all other molecules normally associated with it in its native state. More preferably a substantially purified molecule is the predominant species present in a preparation. A substantially purified molecule may be greater than 60% free, preferably 75% free, more preferably 90% free, and most preferably 95% free from the other molecules (exclusive of solvent) present in the natural mixture. The term "substantially purified" is not intended to encompass molecules present in their native state.

The agents of the invention may also be recombinant. As used herein, the term recombinant means any agent (e.g., DNA, peptide etc.), that is, or results, however indirect, from human manipulation of a nucleic acid molecule.

It is understood that the agents of the invention may be labeled with reagents that facilitate detection of the agent (e.g., fluorescent labels, Prober et al., *Science* 238:336-340 (1987); Albarella et al., EP 144914; chemical labels, Sheldon et al., U.S. Pat. No. 4,582,789; Albarella et al., U.S. Pat. No. 4,563,417; modified bases, Mivoshi et al., EP 119448, all of which are hereby incorporated by reference in their entirety). It is further understood that the invention provides recombinant bacterial, mammalian, microbial, archaeobacterial, insect, fungal, and plant cells as well as viral constructs comprising the agents of the invention.

(a) Nucleic Acid Molecules

Agents of the invention include nucleic acid molecules and, more preferably, nucleic acid molecules of maize, soybean, canola, yeast, or Arabidopsis. In addition, a number of different plants can be the ultimate source of the nucleic acid molecules of the invention. An exemplary group of genotypes includes: B73 (Illinois Foundation Seeds, Champaign, Ill. U.S.A.); B73 x Mol7 (Illinois Foundation Seeds, Champaign, Ill. U.S.A.); DK604 (Dekalb Genetics, Dekalb, Ill. U.S.A.); H99 (Illinois Foundation Seeds, Champaign, Ill. U.S.A.); RX601 (Asgrow Seed Company, Des Moines, Iowa); and Mol7 (Illinois Foundation Seeds, Champaign, Ill. U.S.A.). And an exemplary group of soybean types includes: Asgrow 3244 (Asgrow Seed Company, Des Moines, Iowa); C1944 (United States Department of Agriculture (USDA) Soybean Germplasm Collection, Urbana, Ill. U.S.A.); Cristalina (USDA Soybean Germplasm Collection, Urbana, Ill. U.S.A.); FT108 (Monsoy, Brazil); Hartwig (USDA Soybean Germplasm Collection, Urbana, Ill. U.S.A.); BW211S Null (Tohoku University, Morioka, Japan), PI507354 (USDA Soybean Germplasm Collection, Urbana, Ill. U.S.A.); Asgrow A4922 (Asgrow Seed Company, Des Moines, Iowa U.S.A.); PI227687 (USDA Soybean Germplasm Collection, Urbana, Ill. U.S.A.); PI229358 (USDA Soybean Germplasm Collection, Urbana, Ill. U.S.A.); and Asgrow A3237 (Asgrow Seed Company, Des Moines, Iowa U.S.A.).

A particularly preferred embodiment of the nucleic acid molecules of the present invention are plant nucleic acid molecules that comprise a nucleic acid sequence which encodes an oxysterol-binding protein consensus sequence, for example, soybean HES1 (SEQ ID NOS: 622, 623 and 624), and maize HES1 (SEQ ID NO: 625).

Another particularly preferred embodiment of the nucleic acid molecules of the present invention are yeast nucleic acid molecules that comprise a nucleic acid sequence which encodes an oxysterol-binding protein consensus sequence, for example yeast HES1 (SEQ ID NO: 626).

A particularly preferred embodiment of the nucleic acid molecules of the invention are nucleic acid molecules that encode a protein or fragment thereof where the protein or fragment thereof is selected from the group consisting of a HES1, HMGC_oA reductase, squalene synthase, cycloartenol synthase, SMTI, SMTII and UPC2. In a more particularly preferred embodiment of the nucleic acid molecules of the present invention are nucleic acid molecules that encode a protein or fragment thereof where the protein or fragment thereof is selected from the group consisting of a fungal, more preferably a yeast HES1, a plant, more preferably a maize, soybean or Arabidopsis HES1, a plant, more preferably a rubber or an Arabidopsis HMGC_oA reductase, a plant, more preferably an Arabidopsis squalene synthase, a plant, more preferably an Arabidopsis cycloartenol synthase, a plant, more preferably an Arabidopsis SMTI or SMTII and a fungus, more preferably a yeast UPC2.

In a preferred embodiment, the nucleic molecule encodes a HES1 protein, preferably a plant HES1 protein comprising an oxysterol-binding protein consensus sequence—E(K, Q) xSH (H, R)PPx (S, T, A, C, F)A. In a further preferred embodiment, the nucleic acid molecule encodes a HES1 protein comprising an amino acid sequence selected from the group consisting of SEQ ID NO: 622, SEQ ID NO: 623, SEQ ID NO: 624 and SEQ ID NO: 625. In a further preferred embodiment, the nucleic acid molecule encodes a HES1 protein with a conservative amino acid substitution in an amino acid sequence selected from the group consisting of SEQ ID NO: 622, SEQ ID NO: 623, SEQ ID NO: 624 and SEQ ID NO: 625. In a further preferred embodiment, the nucleic acid molecule encodes a HES1 protein with between 2 and 5 conservative amino acid substitutions in an amino acid sequence selected from the group consisting of SEQ ID NO: 622, SEQ ID NO: 623, SEQ ID NO: 624 and SEQ ID NO: 625. In a further preferred embodiment, the nucleic acid molecule encodes a HES1 protein with between 5 and 10 conservative amino acid substitutions in an amino acid sequence selected from the group consisting of SEQ ID NO: 622, SEQ ID NO: 623, SEQ ID NO: 624 and SEQ ID NO: 625. In a further preferred embodiment, the nucleic acid molecule encodes a HES1 protein with more than 10 conservative amino acid substitutions in an amino acid sequence selected from the group consisting of SEQ ID NO: 622, SEQ ID NO: 623, SEQ ID NO: 624 and SEQ ID NO: 625.

In another preferred embodiment, the nucleic molecule encodes a HES1 protein, preferably a yeast HES1 protein comprising an oxysterol-binding protein consensus sequence—E(K, Q) xSH (H, R) PPx (S, T, A, C, F)A. In a further preferred embodiment, the nucleic acid molecule encodes a HES1 protein comprising an amino acid sequence SEQ ID NO: 626. In a further preferred embodiment, the nucleic acid molecule encodes a HES1 protein with a conservative amino acid substitution in amino acid sequence SEQ ID NO: 626. In a further preferred embodiment, the nucleic acid molecule encodes a

HES1 protein with between 2 and 5 conservative amino acid substitutions in an amino acid sequence SEQ ID NO: 626. In a further preferred embodiment, the nucleic acid molecule encodes a HES1 protein with between 5 and 10 conservative amino acid substitutions in an amino acid sequence SEQ ID NO: 626. In a further preferred embodiment, the nucleic acid molecule encodes a HES1 protein with more than 10 conservative amino acid substitutions in an amino acid sequence SEQ ID NO: 626.

In an aspect of the present invention, one or more of the nucleic acid molecules of the present invention differ in nucleic acid sequence from those encoding a protein or fragment thereof in SEQ ID NO: 1 through SEQ ID NO: 621 due to the degeneracy in the genetic code in that they encode the same protein but differ in nucleic acid sequence. In another further aspect of the present invention, one or more of the nucleic acid molecules of the present invention differ in nucleic acid sequence from those encoding a protein or fragment thereof in SEQ ID NO: 1 through SEQ ID NO: 621 due to the fact that the different nucleic acid sequence encodes a protein having one or more conservative amino acid residue. Examples of conservative substitutions are set forth in Table 1. It is understood that codons capable of coding for such conservative substitutions are known in the art.

TABLE 1

Original Residue	Conservative Substitutions
Ala	Ser
Arg	Lys
Asn	Gln; His
Asp	Glu
Cys	Ser; Ala
Gln	Asn
Glu	Asp
Gly	Pro
His	Asn; Gln
Ile	Leu; Val
Leu	Ile; Val
Lys	Arg; Gln; Glu
Met	Leu; Ile
Phe	Met; Leu; Tyr
Ser	Thr
Thr	Ser
Trp	Tyr
Tyr	Trp; Phe
Val	Ile; Leu

In a further aspect of the present invention, one or more of the nucleic acid molecules of the present invention differ in nucleic acid sequence from those encoding a protein or fragment thereof set forth in SEQ ID NO: 1 through SEQ ID NO: 621 or fragment thereof due to the fact that one or more codons encoding an amino acid has been substituted for a codon that encodes a nonessential substitution of the amino acid originally encoded.

One subset of the nucleic acid molecules of the invention is fragment nucleic acids molecules. Fragment nucleic acid molecules may consist of significant portion(s) of, or indeed most of, the nucleic acid molecules of the invention, such as those specifically disclosed. Alternatively, the fragments may comprise smaller oligonucleotides (having from about 15 to about 400 nucleotide residues and more preferably, about 15 to about 30 nucleotide residues, or about 50 to about 100 nucleotide residues, or about 100 to about 200 nucleotide residues, or about 200 to about 400 nucleotide residues, or about 275 to about 350 nucleotide residues).

A fragment of one or more of the nucleic acid molecules of the invention may be a probe and specifically a PCR probe. A PCR probe is a nucleic acid molecule capable of

initiating a polymerase activity while in a double-stranded structure with another nucleic acid. Various methods for determining the structure of PCR probes and PCR techniques exist in the art. Computer generated searches using programs such as Primer3 (www-genome.wi.mit.edu/cgi-bin/primer/primer3.cgi), STSPipeline (www-genome.wi.mit.edu/cgi-bin/www-STSPipeline), or GeneUp (Pesole et al., *BioTechniques* 25:112-123 (1998)), for example, can be used to identify potential PCR primers.

As used herein, two nucleic acid molecules are said to be capable of specifically hybridizing to one another if the two molecules are capable of forming an anti-parallel, double-stranded nucleic acid structure.

A nucleic acid molecule is said to be the "complement" of another nucleic acid molecule if they exhibit complete complementarity. As used herein, molecules are said to exhibit "complete complementarity" when every nucleotide of one of the molecules is complementary to a nucleotide of the other. Two molecules are said to be "minimally complementary" if they can hybridize to one another with sufficient stability to permit them to remain annealed to one another under at least conventional "low-stringency" conditions. Similarly, the molecules are said to be "complementary" if they can hybridize to one another with sufficient stability to permit them to remain annealed to one another under conventional "high-stringency" conditions. Conventional stringency conditions are described by Sambrook et al., *Molecular Cloning, A Laboratory Manual*, 2nd Ed., Cold Spring Harbor Press, Cold Spring Harbor, N.Y. (1989) and by Haymes et al. *Nucleic Acid Hybridization, A Practical Approach*, IRL Press, Washington, D.C. (1985). Departures from complete complementarity are therefore permissible, as long as such departures do not completely preclude the capacity of the molecules to form a double-stranded structure. Thus, in order for a nucleic acid molecule to serve as a primer or probe it need only be sufficiently complementary in sequence to be able to form a stable double-stranded structure under the particular solvent and salt concentrations employed.

Appropriate stringency conditions which promote DNA hybridization are, for example, 6.0x sodium chloride/sodium citrate (SSC) at about 45° C., followed by a wash of 2.0xSSC at 20-25° C., are known to those skilled in the art or can be found in *Current Protocols in Molecular Biology*, John Wiley & Sons, N.Y. (1989), 6.3.1-6.3.6. For example, the salt concentration in the wash step can be selected from a low stringency of about 2.0xSSC at 50° C. to a high stringency of about 0.2xSSC at 65° C. In addition, the temperature in the wash step can be increased from low stringency conditions at room temperature, about 22° C., to high stringency conditions at about 65° C. Both temperature and salt may be varied, or either the temperature or the salt concentration may be held constant while the other variable is changed.

In a preferred embodiment, a nucleic acid of the invention will specifically hybridize to one or more of the nucleic acid molecules set forth in SEQ ID NO: 1 through SEQ ID NO: 621 or complements thereof or more preferably to a nucleic acid molecule having a nucleic acid sequence selected from the group consisting of SEQ ID NO: 1 through SEQ ID NO: 4, SEQ ID NO: 6 through SEQ ID NO: 29 or complements thereof under moderately stringent conditions, for example at about 2.0xSSC and about 65° C.

In a particularly preferred embodiment, a nucleic acid of the invention will include those nucleic acid molecules that specifically hybridize to one or more of the nucleic acid

molecules set forth in SEQ ID NO: 1 through SEQ ID NO: 621 or complements thereof or more preferably to a nucleic acid molecule having a nucleic acid sequence selected from the group consisting of SEQ ID NO: 1 through SEQ ID NO: 4, SEQ ID NO: 6 through SEQ ID NO: 29 or complements thereof under high stringency conditions such as 0.2xSSC and about 65° C.

In one aspect of the invention, the nucleic acid molecules of the invention have one or more of the nucleic acid sequences set forth in SEQ ID NO: 1 through SEQ ID NO: 621 or complements thereof or fragment thereof or more preferably to a nucleic acid molecule having SEQ ID NO: 1 through SEQ ID NO: 4, SEQ ID NO: 6 through SEQ ID NO: 29 or complements thereof. In another aspect of the invention, one or more of the nucleic acid molecules of the invention share between about 100% and 70% sequence identity with one or more of the nucleic acid sequences set forth in SEQ ID NO: 1 through SEQ ID NO: 621 or complements thereof or more preferably to a nucleic acid molecule having a nucleic acid sequence selected from the group consisting of SEQ ID NO: 1 through SEQ ID NO: 4, SEQ ID NO: 6 through SEQ ID NO: 29 or complements thereof. In a further aspect of the invention, one or more of the nucleic acid molecules of the invention share between about 100% and 90% sequence identity with one or more of the nucleic acid sequences set forth in SEQ ID NO: 1 through SEQ ID NO: 621 or complements thereof or more preferably to a nucleic acid molecule having a nucleic acid sequence selected from the group consisting of SEQ ID NO: 1 through SEQ ID NO: 4, SEQ ID NO: 6 through SEQ ID NO: 29 or complements thereof. In a more preferred aspect of the invention, one or more of the nucleic acid molecules of the invention share between about 100% and 95% sequence identity with one or more of the nucleic acid sequences set forth in SEQ ID NO: 1 through SEQ ID NO: 621 or complements thereof or more preferably to a nucleic acid molecule having a nucleic acid sequence selected from the group consisting of SEQ ID NO: 1 through SEQ ID NO: 4, SEQ ID NO: 6 through SEQ ID NO: 29 or complements thereof. In an even more preferred aspect of the invention, one or more of the nucleic acid molecules of the invention share between about 100% and 99% sequence identity with one or more of the sequences set forth in SEQ ID NO: 1 through SEQ ID NO: 621 or complements thereof or more preferably to a nucleic acid molecule having a nucleic acid sequence selected from the group consisting of SEQ ID NO: 1 through SEQ ID NO: 4, SEQ ID NO: 6 through SEQ ID NO: 29 or complements thereof.

In a preferred embodiment the percent identity calculations are performed using the Megalign program of the LASERGENE bioinformatics computing suite (default parameters, DNASTAR Inc., Madison, Wis.).

In a preferred embodiment of the present invention, the nucleic acid molecule of the present invention encodes a protein or fragment thereof, where a protein exhibits a BLAST probability score of greater than IE-12, preferably a BLAST probability score of between about IE-30 and about IE-12, even more preferably a BLAST probability score of greater than IE-30 with its homologue.

In a preferred embodiment of the present invention, the nucleic acid molecule of the present invention encodes a protein or fragment thereof where a protein exhibits a BLAST score of greater than 120, preferably a BLAST score of between about 1450 and about 120, even more preferably a BLAST score of greater than 1450 with its homologue.

Nucleic acid molecules of the present invention can comprise sequences that encode a protein or fragment

thereof. Such proteins or fragments thereof include homologous of known proteins in other organisms.

A nucleic acid molecule of the invention can also encode a homolog protein. As used herein, a homolog protein molecule or fragment thereof is a counterpart protein molecule or fragment thereof in a second species (e.g., maize HES1 is a homolog of Arabidopsis HES1). A homolog can also be generated by molecular evolution or DNA shuffling techniques, so that the molecule retains at least one functional or structure characteristic of the original protein (see, for example, U.S. Pat. No. 5,811,238).

Particularly preferred homologues are selected from the group consisting of alfalfa, Arabidopsis, barley, Brassica, broccoli, cabbage, citrus, cotton, garlic, oat, oilseed rape, onion, canola, flax, an ornamental plant, maize, peanut, pepper, potato, rice, rye, sorghum, soybean, strawberry, sugarcane, sugarbeet, tomato, wheat, poplar, pine, fir, eucalyptus, apple, lettuce, lentils, grape, banana, tea, turf grasses, sunflower, soybean, and Phaseolus. A particularly preferred group of homologues are crops harvested for seed oils, including but not limited to rapeseed (high erucic acid rape and canola), maize, soybean, safflower, sunflower, cotton, peanut, flax, oil palm and Cuphea.

In a preferred embodiment, nucleic acid molecules having SEQ ID NO: 1 through SEQ ID NO: 621 or complements and fragments of either can be utilized to obtain such homologues.

The degeneracy of the genetic code, which allows different nucleic acid sequences to code for the same protein or peptide, is known in the literature. (U.S. Pat. No. 4,757,006, the entirety of which is herein incorporated by reference).

Agents of the invention include nucleic acid molecules that encode a substantially purified nucleic acid molecules encoding at least about a 10 amino acid region, more preferably a 20, 30, 40, or 50 amino acid region, of a protein selected from the group consisting of a fungal, more preferably a yeast HES1, a plant, more preferably a maize, soybean or Arabidopsis HES1, a plant, more preferably a rubber or an Arabidopsis HMGCoA reductase, a plant, more preferably an Arabidopsis squalene synthase, a plant, more preferably an Arabidopsis cycloartenol synthase, a plant, more preferably an Arabidopsis SMTI or SMTII and a fungus, more preferably a yeast UPC2.

(b) Protein and Peptide Molecules

A class of agents comprises one or more of the protein or fragments thereof or peptide molecules having as nucleic acid sequence selected from the group consisting of SEQ ID NO: 1 through SEQ ID NO: 621 or one or more of the protein or fragment thereof and peptide molecules encoded by other nucleic acid agents of the invention. A particular preferred class of proteins are those having an amino acid sequence selected from the group consisting of SEQ ID NO: 622 through SEQ ID NO: 625 or fragments thereof.

As used herein, the term "protein molecule" or "peptide molecule" includes any molecule that comprises five or more amino acids. It is well known in the art that proteins may undergo modification, including post-translational modifications, such as, but not limited to, disulfide bond formation, glycosylation, phosphorylation, or oligomerization. Thus, as used herein, the term "protein molecule" or "peptide molecule" includes any protein molecule that is modified by any biological or non-biological process. The terms "amino acid" and "amino acids" refer to all naturally occurring L-amino acids. This definition is meant to include norleucine, norvaline, ornithine, homocysteine, and homoserine.

One or more of the protein or fragment of peptide molecules may be produced via chemical synthesis, or more preferably, by expressing in a suitable bacterial or eukaryotic host. Suitable methods for expression are described by Sambrook et al., *In: Molecular Cloning, A Laboratory Manual*, 2nd Edition, Cold Spring Harbor Press, Cold Spring Harbor, N.Y. (1989), or similar texts.

A "protein fragment" is a peptide or polypeptide molecule whose amino acid sequence comprises a subset of the amino acid sequence of that protein. A protein or fragment thereof that comprises one or more additional peptide regions not derived from that protein is a "fusion" protein. Such molecules may be derivatized to contain carbohydrate or other moieties (such as keyhole limpet hemocyanin, etc.). Fusion protein or peptide molecules of the invention are preferably produced via recombinant means.

Another class of agents comprise protein or peptide molecules or fragments or fusions thereof comprising SEQ ID NO: 622 through SEQ NO: 625 or fragment thereof or encoded by SEQ ID NO: 1 through SEQ ID NO: 621 in which conservative, nonessential or non-relevant amino acid residues have been added, replaced or deleted. Computerized means for designing modifications in protein structure are known in the art (Dahiyat and Mayo, *Science* 278:82-87 (1997), the entirety of which is herein incorporated by reference).

A particularly preferred embodiment of the nucleic acid molecules of the present invention are proteins comprising an amino acid sequence which corresponds to an oxysterol-protein binding consensus sequence.

In a preferred embodiment of the present invention, the nucleic molecule of the present invention encodes a protein or fragment thereof, where a protein exhibits a BLAST probability score of greater than 1E-12, preferably a BLAST probability score of between about 1E-30 and about 1E-12, even more preferably a BLAST probability score of greater than 1E-30 with its homologue.

In a preferred embodiment of the present invention, the nucleic molecule of the present invention encodes a protein or fragment thereof where a protein exhibits a BLAST score of greater than 120, preferably a BLAST score of between about 1450 and about 120, even more preferably a BLAST score of greater than 1450 with its homologue.

In another preferred embodiment of the present invention, the nucleic acid molecule encoding a protein or fragment thereof exhibits a % identity with its homologue of between about 25% and about 40%, more preferably of between about 40 and about 70%, even more preferably of between about 70% and about 90% and even more preferably between about 90% and 99%. In another preferred embodiment of the present invention, a protein or fragments thereof exhibits a % identity with its homologue of 100%.

In a preferred embodiment the percent identity calculations are performed using the Megalign program of the LASERGENE bioinformatics computing suite (default parameters, DNASTAR Inc., Madison, Wis.).

A protein of the invention can also be a homologue protein. As used herein, a homologue protein molecule or fragment thereof is a counterpart protein molecule or fragment thereof in a second species (e.g., maize HMGCoA reductase is a homologue of Arabidopsis HMGCoA reductase). A homologue can also be generated by molecular evolution or DNA shuffling techniques, so that the molecule retains at least one functional or structure characteristic of the original (see, for example, U.S. Pat. No. 5,811,238, the entirety of which is herein incorporated by reference).

Particularly preferred homologous are selected from the group consisting of alfalfa, Arabidopsis, barley, Brassica, broccoli, cabbage, citrus, cotton, garlic, oat, oilseed rape, onion, canola, flax, an ornamental plant, maize, peanut, pepper, potato, rice, rye, sorghum, soybean, strawberry, sugarcane, sugarbeet, tomato, wheat, poplar, pine, fir, eucalyptus, apple, lettuce, lentils, grape, banana, tea, turf grasses, sunflower, soybean, and Phaseolus. A particularly preferred group of homologues are those from oil plants such as cotton, canola and sunflower.

In a preferred embodiment, nucleic acid molecules having SEQ ID NO: 1 through SEQ ID NO: 621 or complements and fragments of either can be utilized to obtain such homologues.

The degeneracy of the genetic code, which allows different nucleic acid sequences to code for the same protein or peptide, is known in the literature. (U.S. Pat. No. 4,757,006, the entirety of which is herein incorporated by reference).

Agents of the invention include proteins comprising at least about a 10 amino acid region, more preferably a 20, 30, 40, or 50 amino acid region, of a protein selected from the group consisting of a fungal, more preferably a yeast HES1, a plant, more preferably a maize, soybean or Arabidopsis HES1, a plant, more preferably a rubber or an Arabidopsis HMGCoA reductase, a plant, more preferably an Arabidopsis squalene synthase, a plant, more preferably an Arabidopsis cycloartenol synthase, a plant, more preferably an Arabidopsis SMTI or SMTII and a fungus, more preferably a yeast UPC2.

(c) Plant Constructs and Plant Transformants

One or more of the nucleic acid molecules of the invention may be used in plant transformation or transfection. Exogenous genetic material may be transferred into a plant cell and the plant cell regenerated into a whole, fertile or sterile plant. Exogenous genetic material is any genetic material, whether naturally occurring or otherwise, from any source that is capable of being inserted into any organism. In a preferred embodiment the exogenous genetic material includes a nucleic acid molecule of the present invention, preferably a nucleic acid molecule having a sequence selected from the group consisting of SEQ ID NO: 1 through SEQ ID NO: 621 or complements thereof or fragments of either. Another preferred class of exogenous genetic material are nucleic acid molecules that encode a protein having an amino acid selected from the group consisting of SEQ ID NO: 622 through SEQ ID NO: 626 or fragments thereof.

Genetic material may be transferred into either monocotyledons and dicotyledons including, but not limited to maize, soybean, Arabidopsis, phaseolus, peanut, alfalfa, wheat, rice, oat, sorghum, rye, titordeum, millet, fescue, perennial ryegrass, sugarcane, cranberry, papaya, banana, banana, muskmelon, apple, cucumber, dendrobium, gladiolus, chrysanthemum, liliacea, cotton, eucalyptus, sunflower, canola, turfgrass, sugarbeet, coffee and dioscorea (Christou, In: *Particle Bombardment for Genetic Engineering of Plants*, Biotechnology Intelligence Unit, Academic Press, San Diego, Calif. (1996), the entirety of which is herein incorporated by reference). In a particular preferred embodiment, any seed-bearing plant may be employed as the target plant species for modification in accordance with this invention, including angiosperms, gymnosperms, monocotyledons, and dicotyledons. Plants of special interest are crops harvested for seed oils, including but not limited to rapeseed (high erucic acid rape and canola), maize, soybean, safflower, sunflower, cotton, peanut, flax, oil palm and Cuphea.

Transfer of a nucleic acid that encodes for a protein can result in overexpression of that protein in a transformed cell or transgenic plant. One or more of the proteins or fragments thereof encoded by nucleic acid molecules of the invention may be overexpressed in a transformed cell or transformed plant. Such overexpression may be the result of transient or stable transfer of the exogenous genetic material.

In another preferred aspect of the present invention, exogenous genetic material is a nucleic acid molecule that comprises a nucleic acid sequence which encodes a HES1 protein or fragment thereof, more preferably a yeast HES1 protein or fragment thereof, even more preferably a plant HES1 protein or fragment thereof.

In a preferred embodiment, expression or overexpression of a HES1 protein in a plant provides in that plant, relative to an untransformed plant with a similar genetic background, in increased level of phytosterols.

In a preferred embodiment, expression or overexpression of a HES1 protein in a plant provides in that plant, relative to an untransformed plant with a similar genetic background, an altered composition of phytosterols.

In another embodiment, overexpression of a HES1 protein in a plant provides in that plant, relative to an untransformed plant with a similar genetic background, an increased level of a HES1 protein in a plasmid.

In another preferred embodiment, overexpression of the HES1 protein in a transformed plant will result in a plant which as a food or feed constituent exhibits an increased ability to act as a cholesterol lowering agent relative to an untransformed plant with a similar genetic background.

In a preferred embodiment of the present invention, the protein or fragment thereof overexpressed in the transgenic plant is selected from the group consisting of a HES1, HMGCoA reductase, squalene synthase, cycloartenol synthase, SMTI, SMTII and UPC2. In a more particularly preferred embodiment of the present invention is a protein or fragment thereof, where the protein or fragment thereof is selected from the group consisting of a fungal, more preferably a yeast HES1, a plant, more preferably a maize, soybean or Arabidopsis HES1, a plant, more preferably a rubber or an Arabidopsis HMGCoA reductase, a plant, more preferably an Arabidopsis, squalene synthase, a plant, more preferably an Arabidopsis cycloartenol synthase, a plant, more preferably an Arabidopsis SMTI or SMTII and a plant, more preferably a yeast UPC2.

In another preferred embodiment of the present invention, the protein or fragment thereof overexpressed in the transgenic plant is selected from the group consisting a plant HES1, HMGCoA reductase, squalene synthase, cycloartenol synthase, SMTI, SMTII and yeast UPC2. In a further even more particularly preferred embodiment of the present invention the protein or fragment thereof is a plant HES1. In an additional even more particularly preferred embodiment of the present invention the protein or fragment thereof is a maize, soybean or Arabidopsis HES1.

In another preferred embodiment of the present invention, the protein or fragment thereof overexpressed in the transgenic plant is a HES1 protein, preferably a plant HES1 protein comprising an oxysterol-binding protein consensus sequence—E(K, Q) xSH (H, R) PPx (S, T, A, C, F)A. In another preferred embodiment of the present invention, the protein or fragment thereof overexpressed in the transgenic plant is a HES1 protein that comprises an amino acid sequence selected from the group consisting of SEQ ID NO: 622, SEQ ID NO: 623, SEQ ID NO: 624 and SEQ ID NO: 625. In another preferred embodiment of the present

invention, the protein or fragment thereof overexpressed in the transgenic plant is a HES1 protein with a conservative amino acid substitution in an amino acid sequence selected from the group consisting of SEQ ID NO: 622, SEQ ID NO: 623, SEQ ID NO: 624 and SEQ ID NO: 625. In another preferred embodiment of the present invention, the protein or fragment thereof overexpressed in the transgenic plant is a HES1 protein with between 2 and 5 conservative amino acid substitutions in an amino acid sequence selected from the group consisting of SEQ ID NO: 622, SEQ ID NO: 623, SEQ ID NO: 624 and SEQ ID NO: 625. In another preferred embodiment of the present invention, the protein or fragment thereof overexpressed in the transgenic plant is a HES1 protein with between 5 and 10 conservative amino acid substitutions in an amino acid sequence selected from the group consisting of SEQ ID NO: 622, SEQ ID NO: 623, SEQ ID NO: 624 and SEQ ID NO: 625. In another preferred embodiment of the present invention, the protein or fragment thereof overexpressed in the transgenic plant is a HES1 protein with more than 10 conservative amino acid substitutions in an amino acid sequence selected from the group consisting of SEQ ID NO: 622, SEQ ID NO: 623, SEQ ID NO: 624 and SEQ ID NO: 625.

In another preferred embodiment of the present invention, the protein or fragment thereof overexpressed in the transgenic plant is a HES1 protein that comprises an amino acid sequence SEQ ID NO: 626. In another preferred embodiment of the present invention, the protein or fragment thereof overexpressed in the transgenic plant is a HES1 protein with a conservative amino acid substitution in an amino acid sequence SEQ ID NO: 626. In another preferred embodiment of the present invention, the protein or fragment thereof overexpressed in the transgenic plant is a HES1 protein with between 2 and 5 conservative amino acid substitutions in an amino acid sequence SEQ ID NO: 626. In another preferred embodiment of the present invention, the protein or fragment thereof overexpressed in the transgenic plant is a HES1 protein with between 5 and 10 conservative amino acid substitutions in an amino acid sequence SEQ ID NO: 625. In another preferred embodiment of the present invention, the protein or fragment thereof overexpressed in the transgenic plant is a HES1 protein with more than 10 conservative amino acid substitutions in an amino acid sequence SEQ ID NO: 626.

Exogenous genetic material may be transferred into a host cell by the use of a DNA vector or construct designed for such a purpose. Design of such a vector is generally within the skill of the art (See, *Plant Molecular Biology: A Laboratory Manual*, Clark (ed.), Springer, N.Y. (1997), the entirety of which is herein incorporated by reference).

A construct or vector may include a plant promoter to express the protein or protein fragment of choice. A number of promoters, which are active in plant cells, have been described in the literature. These include the nopaline synthase (NOS) promoter (Ebert et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 84:5745-5749 (1987), the entirety of which is herein incorporated by reference), the octopine synthase (OCS) promoter (which are carried on tumor-inducing plasmids of *Agrobacterium tumefaciens*), the caulimovirus promoters such as the cauliflower mosaic virus (CaMV) 19S promoter (Lawton et al. *Plant Mol. Biol.* 9:315-324 (1987), the entirety of which is herein incorporated by reference) and the CaMV 35S promoter (Odell et al., *Nature* 313:810-812 (1985), the entirety of which is herein incorporated by reference), the figwort mosaic virus 35S-promoter, the light-inducible promoter from the small subunit of ribulose-1,5-bis-phosphate carboxylase

(ssRUBISCO), the Adh promoter (Walker et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 84:6624-6628 (1987), the entirety of which is herein incorporated by reference), the sucrose synthase promoter (Yang et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 87:4144-4148 (1990), the entirety of which is herein incorporated by reference), the R gene complex promoter (Chandler et al., *The Plant Cell* 1:1175-1183 (1989), the entirety of which is herein incorporated by reference) and the chlorophyll a/b binding protein gene promoter, etc. These promoters have been used to create DNA constructs that have been expressed in plants: see, e.g., PCT publication WO 84/02913, herein incorporated by reference in its entirety. The CaMV 35S promoters are preferred for use in plants. Promoters known or found to cause transcription of DNA in plant cells can be used in the invention.

For the purpose of expression in source tissues of the plant, such as the leaf, seed, root or stem, it is preferred that the promoters utilized have relatively high expression in these specific tissues. Tissue-specific expression of a protein of the present invention is a particularly preferred embodiment. For this purpose, one may choose from a number of promoters for genes with tissue- or cell-specific or -enhanced expression. Examples of such promoters reported in the literature include the chloroplast glutamine synthetase GS2 promoter from pea (Edwards et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 87:3459-3463 (1990), herein incorporated by reference in its entirety), the chloroplast fructose-1,6-bisphosphatase (FBPase) promoter from wheat (Lloyd et al., *Mol. Gen. Genet.* 225:209-216 (1991), herein incorporated by reference in its entirety), the nuclear photosynthetic ST-LS1 promoter from potato (Stockhaus et al., *EMBO J.* 8:2445-2451 (1989), herein incorporated by reference in its entirety), the serine/threonine kinase (PAL) promoter and the glucoamylase (CHS) promoter from *Arabidopsis thaliana*. Also reported to be active in photosynthetically active tissues are the ribulose-1,5-bisphosphate carboxylase (RbcS) promoter from eastern larch (*Larix laricina*), the promoter for the cab gene, cab6, from pine (Yamamoto et al., *Plant Cell Physiol.* 35:773-778 (1994), herein incorporated by reference in its entirety), the promoter for the Cab-1 gene from wheat (Fejes et al., *Plant Mol. Biol.* 15:921-932 (1990), herein incorporated by reference in its entirety), the promoter for the CAB-1 gene from spinach (Lubberstedt et al., *Plant Physiol.* 104:997-1006 (1994), herein incorporated by reference in its entirety), the promoter for the cab1R gene from rice (Luan et al., *Plant Cell.* 4:971-981 (1992), the entirety of which is herein incorporated by reference), the pyruvate, orthophosphate dikinase (PPDK) promoter from maize (Matsuoka et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 90: 9586-9590 (1993), herein incorporated by reference in its entirety), the promoter for the tobacco Lhcb1*2 gene (Cerdan et al., *Plant Mol. Biol.* 33:245-255 (1997), herein incorporated by reference in its entirety), the *Arabidopsis thaliana* SUC2 sucrose-H⁺ symporter promoter (Truernit et al., *Planta* 196:564-570 (1995), herein incorporated by reference in its entirety) and the promoter for the thylakoid membrane proteins from spinach (psaD, psaF, psaE, PC, FNR, atpC, atpD, cab, rbcS). Other promoters for the chlorophyll a/b-binding proteins may also be utilized in the invention, such as the promoters for LhcB gene and PsbP gene from white mustard (*Sinapis alba*; Kretsch et al., *Plant Mol. Biol.* 28:219-229 (1995), the entirety of which is herein incorporated by reference).

For the purpose of expression in sink tissues of the plant, such as the tuber of the potato plant, the fruit of tomato, or the seed of maize, wheat, rice and barley, it is preferred that

the promoters utilized in the invention have relatively high expression in these specific tissues. A number of promoters for genes with tuber-specific or -enhanced expression are known, including the class I patatin promoter (Bevan et al., *EMBO J.* 8:1899-1906 (1986); Jefferson et al., *Plant Mol. Biol.* 14:995-1006 (1990), both of which are herein incorporated by reference in their entirety), the promoter for the potato tuber ADPGPP genes, both the large and small subunits, the sucrose synthase promoter (Salanoubat and Belliard, *Gene* 60:47-56 (1987), Salanoubat and Belliard, *Gene* 84:181-185 (1989), both of which are incorporated by reference in their entirety), the promoter for the major tuber proteins including the 22 kd protein complexes and proteinase inhibitors (Hannapel, *Plant Physiol.* 101:703-704 (1993), herein incorporated by reference in its entirety), the promoter for the granule bound starch synthase gene (GBSS) (Visser et al., *Plant Mol. Biol.* 17:691-699 (1991), herein incorporated by reference in its entirety) and other class I and II patatin promoters (Koster-Topfer et al., *Mol Gen Genet.* 219:390-396 (1989); Mignery et al., *Gene*, 62:27-44 (1988), both of which are herein incorporated by reference in their entirety).

Other promoters can also be used to express a protein or fragment thereof in specific tissues, such as seeds or fruits. The promoter for β -conglycinin (Chen et al., *Dev. Genet.* 10: 112-122 (1989), herein incorporated by reference in its entirety) or other seed-specific promoters such as the napin and phaseolin promoters, can be used. The zeins are a group of storage proteins found in maize endosperm. Genomic clones for zein genes have been isolated (Pedersen et al., *Cell* 29:1015-1026 (1982), herein incorporated by reference in its entirety) and the promoters from these clones, including the 15 kD, 16 kD, 19 kD, 22 kD, 27 kD and γ genes, could also be used. Other promoters known to function, for example, in maize include the promoters for the following genes: waxy, Brittle, Shrunken 2, Branching enzymes I and II, starch synthases, debranching enzymes, oleosins, glutelins and sucrose synthases. A particularly preferred promoter for maize endosperm expression is the promoter for the glutelin gene from rice, more particularly the Osgt-1 promoter (Zheng et al., *Mol. Cell Biol.* 13:5829-5842 (1993), herein incorporated by reference in its entirety). Examples of promoters suitable for expression in wheat include those promoters for the ADPglucose pyrosynthase (ADPGPP) subunits, the granule bound and other starch synthase, the branching and debranching enzymes, the embryogenesis-abundant proteins, the gliadins and the glutenins. Examples of such promoters in rice include those promoters for the ADPGPP subunits, the granule bound and other starch synthase, the branching enzymes, the debranching enzymes, sucrose synthases and the glutelins. A particularly preferred promoter is the promoter for rice glutelin, Osgt-1. Examples of such promoters for barley include those for the ADPGPP subunits, the granule bound and other starch synthase, the branching enzymes, the debranching enzymes, sucrose synthases, the hordeins, the embryo globulins and the aleurone specific proteins.

Root specific promoters may also be used. An example of such a promoter is the promoter for the acid chitinase gene (Samac et al., *Plant Mol. Biol.* 25:587-596 (1994), the entirety of which is herein incorporated by reference). Expression in root tissue could also be accomplished by utilizing the root specific subdomains of the CaMV35S promoter that have been identified (Lam et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 86:7890-7894 (1989), herein incorporated by reference in its entirety). Other root cell specific promoters include those reported by Conkling et al.

(Conkling et al., *Plant Physiol.* 93:1203-1211 (1990), the entirety of which is herein incorporated by reference).

Additional promoters that may be utilized are described, for example, in U.S. Pat. Nos. 5,378,619; 5,391,725; 5,428,147; 5,447,858; 5,608,144; 5,608,144; 5,614,399; 5,633,441; 5,633,435; and 4,633,436, all of which are herein incorporated in their entirety. In addition, a tissue specific enhancer may be used (Fromm et al., *The Plant Cell* 1:977-984 (1989), the entirety of which is herein incorporated by reference).

Constructs or vectors may also include, with the coding region of interest, a nucleic acid sequence that acts, in whole or in part, to terminate transcription of that region. A number of such sequences have been isolated, including the Tr7 3' sequence and the NOS 3' sequence (Ingelbrecht et al., *The Plant Cell* 1:671-680 (1989), the entirety of which is herein incorporated by reference; Bevan et al., *Nucleic Acids Res.* 11:369-385 (1983), the entirety of which is herein incorporated by reference).

A vector or construct may also include regulatory elements. Examples of such include the Adh intron 1 (Callis et al., *Genes and Develop.* 1:1183-1200 (1987), the entirety of which is herein incorporated by reference), the sucrose synthase intron (Vasil et al., *Plant Physiol.* 91:1575-1579 (1989), the entirety of which is herein incorporated by reference) and the TMV omega element (Gallie et al., *The Plant Cell* 1:301-311 (1989), the entirety of which is herein incorporated by reference). These and other regulatory elements may be included when appropriate.

A vector or construct may also include a selectable marker. Selectable markers may also be used to select for plants or plant cells that contain the exogenous genetic material. Examples of such include, but are not limited to: a neo gene (Potrykus et al., *Mol. Gen. Genet.* 199:183-188 (1985), the entirety of which is herein incorporated by reference), which codes for kanamycin resistance and can be selected for using kanamycin. G418, etc.: a bar gene which codes for bialaphos resistance: a mutant EPSP synthase gene (Hinchee et al., *Bio/Technology* 6:915-922 (1988), the entirety of which is herein incorporated by reference) which encodes glyphosate resistance: a nitrilase gene which confers resistance to bromoxynil (Stalker et al., *J. Biol. Chem.* 263:6310-6314 (1988), the entirety of which is herein incorporated by reference); a mutant acetolactate synthase gene (ALS) which confers imidazolinone or sulphonylurea resistance (European Patent Application 154,204 (Sep. 11, 1985), the entirety of which is herein incorporated by reference); and a methotrexate resistant DHFR gene (Thillet et al., *J. Biol. Chem.* 263:12500-12508 (1988), the entirety of which is herein incorporated by reference).

A vector or construct may also include a transit peptide. Incorporation of a suitable chloroplast transit peptide may also be employed (European Patent Application Publication Number 0218571, the entirety of which is herein incorporated by reference). Translational enhancers may also be incorporated as part of the vector DNA. DNA constructs could contain one or more 5' -non-translated leader sequences which may serve to enhance expression of the gene products from the resulting mRNA transcripts. Such sequences may be derived from the promoter selected to express the gene or can be specifically modified to increase translation of the mRNA. Such regions may also be obtained from viral RNAs, from suitable eukaryotic genes, or from a synthetic gene sequence. For a review of optimizing expression of transgenes, see Koziel et al., *Plant Mol. Biol.* 32:393-405 (1996), the entirety of which is herein incorporated by reference.

A vector or construct may also include a screenable marker. Screenable markers may be used to monitor expression. Exemplary screenable markers include: a β -glucuronidase or uidA gene (GUS) which encodes an enzyme for which various chromogenic substrates are known (Jefferson, *Plant Mol. Biol. Rep.* 5:387-405 (1987), the entirety of which is herein incorporated by reference; Jefferson et al., *EMBO J.* 6:3901-3907 (1987), the entirety of which is herein incorporated by reference); an R-locus gene, which encodes a product that regulates the production of anthocyanin pigments (red color) in plant tissues (Dellaporta et al., *Stadler Symposium* 11:263-282 (1988), the entirety of which is herein incorporated by reference); a β -lactamase gene (Sutcliffe et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 75:3737-3741 (1978), the entirety of which is herein incorporated by reference), a gene which encodes an enzyme for which various chromogenic substrates are known (e.g., PADAC, a chromogenic cephalosporin): a luciferase gene (Ow et al., *Science* 234:856-859 (1986), the entirety of which is herein incorporated by reference); a xyle gene (Zukowsky et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 80:1101-1105 (1983), the entirety of which is herein incorporated by reference) which encodes a catechol dioxygenase that can convert chromogenic catechols: an α -amylase gene (Ikata et al., *Bio/Technol.* 8:241-242 (1990), the entirety of which is herein incorporated by reference); a tyrosinase gene (Katz et al., *J. Gen. Microbiol.* 129:2703-2714 (1983), the entirety of which is herein incorporated by reference) which encodes an enzyme capable of oxidizing tyrosine to DOPA and dopaquinone which in turn condenses to melanin; an α -galactosidase, which will turn a chromogenic α -galactose substrate.

Included within the terms "selectable or screenable marker genes" are also genes which encode a secretable marker whose secretion can be detected as a means of identifying or selecting for transformed cells. Examples include markers which encode a secretable antigen that can be identified by antibody interaction, or even secretable enzymes which can be detected catalytically. Secretable proteins fall into a number of classes, including small, diffusible proteins which are detectable, (e.g., by ELISA), small active enzymes which are detectable in extracellular solution (e.g., α -amylase, β -lactamase, phosphinothricin transferase), or proteins which are inserted or trapped in the cell wall (such as proteins which include a leader sequence such as that found in the expression unit of extension or tobacco PR-S). Other possible selectable and/or screenable marker genes will be apparent to those of skill in the art.

There are many methods for introducing transforming nucleic acid molecules into plant cells. Suitable methods are believed to include virtually any method by which nucleic acid molecules may be introduced into a cell, such as by *Agrobacterium* infection or direct delivery of nucleic acid molecules such as, for example, by PEG-mediated transformation, by electroporation or by acceleration of DNA coated particles, etc. (Potrykus, *Ann. Rev. Plant Physiol. Plant Mol. Biol.* 42:205-225 (1991), the entirety of which is herein incorporated by reference; Vasil, *Plant Mol. Biol.* 25:925-937 (1994), the entirety of which is herein incorporated by reference). For example, electroporation has been used to transform maize protoplasts (Fromm et al., *Nature* 312:791-793 (1986), the entirety of which is herein incorporated by reference).

Other vector systems suitable for introducing transforming DNA into a host plant cell include but are not limited to binary artificial chromosome (BIBAC) vectors (Hamilton et al., *Gene* 200:107-116 (1997), the entirety of which is herein

incorporated by reference); and transfection with RNA viral vectors (Della-Cioppa et al., *Ann. N.Y. Acad. Sci.* (1996), 792 (Engineering Plants for Commercial Products and Applications), 57-61, the entirety of which is herein incorporated by reference). Additional vector systems also include plant selectable YAC vectors such as those described in Mullen et al., *Molecular Breeding* 4:449-457 (1988), the entirety of which is herein incorporated by reference).

Technology for introduction of DNA into cells is well known to those of skill in the art. Four general methods for delivering a gene into cells have been described: (1) chemical methods (Graham and van der Eb, *Virology* 54:536-539 (1973), the entirety of which is herein incorporated by reference); (2) physical methods such as microinjection (Capecchi, *Cell* 22:479-488 (1980), the entirety of which is herein incorporated by reference), electroporation (Wong and Neumann, *Biochem. Biophys. Res. Commun.* 107:584-587 (1982); Fromm et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 82:5824-5828 (1985); U.S. Pat. No. 5,384,253, all of which are herein incorporated in their entirety); and the gene gun (Johnston and Tang, *Methods Cell Biol.* 43:353-365 (1994), the entirety of which is herein incorporated by reference); (3) viral vectors (Clapp, *Clin. Perinatol.* 20:155-168 (1993); Lu et al., *J. Exp. Med.* 178:2089-2096 (1993); Eglitis and Anderson, *Biotechniques* 6:608-614 (1988), all of which are herein incorporated in their entirety); and (4) receptor-mediated mechanisms (Curiel et al., *Hum. Gen. Ther.* 3:147-154 (1992), Wagner et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 89:6099-6103 (1992), both of which are incorporated by reference in their entirety).

Acceleration methods that may be used include, for example, microprojectile bombardment and the like. One example of a method for delivering transforming nucleic acid molecules to plant cells is microprojectile bombardment. This method has been reviewed by Yang and Christou (eds.), *Particle Bombardment Technology for Gene Transfer*, Oxford Press, Oxford, England (1994), the entirety of which is herein incorporated by reference). Non-biological particles (microprojectiles) that may be coated with nucleic acids and delivered into cells by a propelling force. Exemplary particles include those comprised of tungsten, gold, platinum and the like.

A particular advantage of microprojectile bombardment, in addition to it being an effective means of reproducibly transforming monocots, is that neither the isolation of protoplasts (Cristou et al., *Plant Physiol.* 87:671-674 (1988), the entirety of which is herein incorporated by reference) nor the susceptibility of *Agrobacterium* infection are required. An illustrative embodiment of a method for delivering DNA into maize cells by acceleration is a biolistics α -particle delivery system, which can be used to propel particles coated with DNA through a screen, such as a stainless steel or Nytex screen, onto a filter surface covered with maize cells cultured in suspension. Gordon-Kamm et al., describes the basic procedure for coating tungsten particles with DNA (Gordon-Kamm et al., *Plant Cell* 2:603-618 (1990), the entirety of which is herein incorporated by reference). The screen disperses the tungsten nucleic acid particles so that they are not delivered to the recipient cells in large aggregates. A particle delivery system suitable for use with the invention is the helium acceleration PDS-1000/He gun is available from Bio-Rad Laboratories (Bio-Rad, Hercules, Calif.) (Sanford et al., *Technique* 3:3-16 (1991), the entirety of which is herein incorporated by reference).

For the bombardment, cells in suspension may be concentrated on filters. Filters containing the cells to be bombarded are positioned at an appropriate distance below the

microprojectile stopping plate. If desired, one or more screens are also positioned between the gun and the cells to be bombarded.

Alternatively, immature embryos or other target cells may be arranged on solid culture medium. The cells to be bombarded are positioned at an appropriate distance below the microprojectile stopping plate. If desired, one or more screens are also positioned between the acceleration device and the cells to be bombarded. Through the use of techniques set forth herein one may obtain up to 1000 or more foci of cells transiently expressing a marker gene. The number of cells in a focus which express the exogenous gene product 48 hours post-bombardment often range from one to ten and average one to three.

In bombardment transformation, one may optimize the pre-bombardment culturing conditions and the bombardment parameters to yield the maximum numbers of stable transformants. Both the physical and biological parameters for bombardment are important in this technology. Physical factors are those that involve manipulating the DNA/microprojectile precipitate or those that affect the flight and velocity of either the macro- or microprojectiles. Biological factors include all steps involved in manipulation of cells before and immediately after bombardment, the osmotic adjustment of target cells to help alleviate the trauma associated with bombardment and also the nature of the transforming DNA, such as linearized DNA or intact supercoiled plasmids. It is believed that pre-bombardment manipulations are especially important for successful transformation of immature embryos.

In another alternative embodiment, plasmids can be stably transformed. Methods disclosed for plasmid transformation in higher plants include the particle gun delivery of DNA containing a selectable marker and targeting of the DNA to the plasmid genome through homologous recombination (Svab et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 87:8526-8530 (1990); Svab and Maliga, *Proc. Natl. Acad. Sci. (U.S.A.)* 90:913-917 (1993); Staub and Maliga, *EMBO J.* 12:601-606 (1993); U.S. Pat. Nos. 5,451,513 and 5,545,818, all of which are herein incorporated by reference in their entirety).

Accordingly, it is contemplated that one may wish to adjust various aspects of the bombardment parameters in small scale studies to fully optimize the conditions. One may particularly wish to adjust physical parameters such as gap distance, flight distance, tissue distance and helium pressure. One may also minimize the trauma reduction factors by modifying conditions which influence the physiological state of the recipient cells and which may therefore influence transformation and integration efficiencies. For example, the osmotic state, tissue hydration and the subculture stage or cell cycle of the recipient cells may be adjusted for optimum transformation. The execution of other routine adjustments will be known to those of skill in the art in light of the present disclosure.

Agrobacterium-mediated transfer is a widely applicable system for introducing genes into plant cells because the DNA can be introduced into whole plant tissues, thereby bypassing the need for regeneration of an intact plant from a protoplast. The use of Agrobacterium-mediated plant integrating vectors to introduce DNA into plant cells is well known in the art. See, for example the methods described by Fraley et al., *Bio/Technology* 3:629-635 (1985) and Rogers et al., *Methods Enzymol.* 153:253-277 (1987), both of which are herein incorporated by reference in their entirety. Further, the integration of the Ti-DNA is a relatively precise

process resulting in few rearrangements. The region of DNA to be transferred is defined by the border sequences and intervening DNA is usually inserted into the plant genome as described (Spielmann et al., *Mol. Gen. Genet.* 205:34 (1986), the entirety of which is herein incorporated by reference).

Modern Agrobacterium transformation vectors are capable of replication in *E. coli* as well as Agrobacterium, allowing for convenient manipulations as described (Klee et al., In: *Plant DNA Infectious Agents*, Hohn and Schell (eds.), Springer-Verlag, New York, pp. 179-203 (1985), the entirety of which is herein incorporated by reference). Moreover, technological advances in vectors for Agrobacterium-mediated gene transfer have improved the arrangement of genes and restriction sites in the vectors to facilitate construction of vectors capable of expressing various polypeptide coding genes. The vectors described have convenient multi-linker regions flanked by a promoter and a polyadenylation site for direct expression of inserted polypeptide coding genes and are suitable for present purposes (Rogers et al., *Method Enzymol.* 153:253-277 (1987)). In addition, Agrobacterium containing both armed and disarmed Ti genes can be used for the transformations. In those plant strains where Agrobacterium-mediated transformation is efficient, it is the method of choice because of the facile and defined nature of the gene transfer. A transgenic plant formed using Agrobacterium transformation methods typically contains a single gene on one chromosome. Such transgenic plants can be referred to as being heterozygous for the added gene. More preferred is a transgenic plant that is homozygous for the added structural gene; i.e., a transgenic plant that contains two added genes, one gene at the same locus on each chromosome of a chromosome pair. A homozygous transgenic plant can be obtained by sexually mating (selfing) an independent segregating transgenic plant that contains a single added gene, germinating some of the seed produced and analyzing the resulting plants produced for the gene of interest.

It is also to be understood that two different transgenic plants can also be mated to produce offspring that contain two independently segregating, exogenous genes. Selfing of appropriate progeny can produce plants that are homozygous for both added, exogenous genes that encode a polypeptide of interest. Back-crossing to a parental plant and out-crossing with a non-transgenic plant are also contemplated, as is vegetative propagation.

Transformation of plant protoplasts can be achieved using methods based on calcium phosphate precipitation, polyethylene glycol treatment, electroporation and combinations of these treatments (See, for example, Potrykus et al., *Mol. Gen. Genet.* 205:193-200 (1986); Lorz et al., *Mol. Gen. Genet.* 199:178 (1985); Fromm et al., *Nature* 319:791 (1986); Uchimiya et al., *Mol. Gen. Genet.* 204:204 (1986); Marcotte et al., *Nature* 335:454-457 (1988), all of which are herein incorporated by reference in their entirety).

Application of these systems to different plant strains depends upon the ability to regenerate that particular plant strain from protoplasts. Illustrative methods for the regeneration of cereals from protoplasts are described (Fujimura et al., *Plant Tissue Culture Letters* 2:74 (1985); Toriyama et al., *Theor Appl. Genet.* 205:34 (1986); Yamada et al., *Plant Cell Rep.* 4:85 (1986); Abdullah et al., *Biotechnolog.* 4:1087 (1986), all of which are herein incorporated by reference in their entirety).

To transform plant strains that cannot be successfully regenerated from protoplasts, other ways to introduce DNA

into intact cells or tissues can be utilized. For example, regeneration of cereals from immature embryos or explants can be effected as described (Vasil, *Biotechnology* 6:397 (1988), the entirety of which is herein incorporated by reference). In addition, "particle gun" or high-velocity microprojectile technology can be utilized (Vasil et al., *Bio/Technology* 10:667 (1992), the entirety of which is herein incorporated by reference).

Using the latter technology, DNA is carried through the cell wall and into the cytoplasm on the surface of small metal particles as described (Klein et al., *Nature* 328:70 (1987); Klein et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 85:8502-8505 (1988); McCabe et al., *Bio/Technology* 6:923 (1988), all of which are herein incorporated by reference in their entirety). The metal particles penetrate through several layers of cells and thus allow the transformation of cells within tissue explants.

Other methods of cell transformation can also be used and include but are not limited to introduction of DNA into plants by direct DNA transfer into pollen (Hess et al., *Intern Rev. Cytol.* 107:367 (1987); Luo et al., *Plant Mol. Biol. Reporter* 6:165 (1988), all of which are herein incorporated by reference in their entirety), by direct injection of DNA into reproductive organs of a plant (Pena et al., *Nature* 325:274 (1987), the entirety of which is herein incorporated by reference), or by direct injection of DNA into the cells of immature embryos followed by the rehydration of desiccated embryos (Neuhaus et al., *Theor. Appl. Genet.* 75:30 (1987), the entirety of which is herein incorporated by reference).

The regeneration, development and cultivation of plants from single plant protoplast transformants or from various transformed explants is well known in the art (Weissbach and Weissbach, In: *Methods for Plant Molecular Biology*, Academic Press, San Diego, Calif., (1988), the entirety of which is herein incorporated by reference). This regeneration and growth process typically includes the steps of selection of transformed cells, culturing those individualized cells through the usual stages of embryonic development through the rooted plantlet stage. Transgenic embryos and seeds are similarly regenerated. The resulting transgenic rooted shoots are thereafter planted in an appropriate plant growth medium such as soil.

The development or regeneration of plants containing the foreign, exogenous gene that encodes a protein of interest is well known in the art. Preferably, the regenerated plants are self pollinated to provide homozygous transgenic plants. Otherwise, pollen obtained from the regenerated plants is crossed to seed-grown plants of agronomically important lines. Conversely, pollen from plants of these important lines is used to pollinate regenerated plants. A transgenic plant of the invention containing a desired polypeptide is cultivated using methods well known to one skilled in the art.

There are a variety of methods for the regeneration of plants from plant tissue. The particular method of regeneration will depend on the starting plant tissue and the particular plant species to be regenerated.

Methods for transforming dicots, primarily by use of *Agrobacterium tumefaciens* and obtaining transgenic plants have been published for cotton (U.S. Pat. Nos. 5,004,863; 5,159,135; 5,518,908, all of which are herein incorporated by reference in their entirety); soybean (U.S. Pat. Nos. 5,569,834; 5,416,011; McCabe et al., *Biotechnology* 6:923 (1988); Christou et al., *Plant Physiol.* 87:671-674 (1988); all of which are herein incorporated by reference in their entirety); Brassica (U.S. Pat. No. 5,463,174, the entirety of

which is herein incorporated by reference); peanut (Cheng et al., *Plant Cell Rep.* 15:653-657 (1996), McKentley et al., *Plant Cell Rep.* 14:699-703 (1995), all of which are herein incorporated by reference in their entirety); papaya; and pea (Grant et al., *Plant Cell Rep.* 15:254-258 (1995), the entirety of which is herein incorporated by reference).

Transformation of monocotyledons using electroporation, particle bombardment and *Agrobacterium* have also been reported. Transformation and plant regeneration have been achieved in asparagus (Bytebier et al., *Proc. Natl. Acad. Sci. (USA)* 84:5354 (1987), the entirety of which is herein incorporated by reference); barley (Wan and Lemaux, *Plant Physiol* 104:37 (1994), the entirety of which is herein incorporated by reference); maize (Rhodes et al., *Science* 240:204 (1988); Gordon-Kamm et al., *Plant Cell* 2:603-618 (1990); Fromm et al., *Bio/Technology* 8:833 (1990); Kozziel et al., *Bio/Technology* 11:194 (1993); Armstrong et al., *Crop Science* 35:550-557 (1995); all of which are herein incorporated by reference in their entirety); oat (Somers et al., *Bio/Technology* 10:1589 (1992), the entirety of which is herein incorporated by reference); orchard grass (Horn et al., *Plant Cell Rep.* 7:469 (1988), the entirety of which is herein incorporated by reference); rice (Toriyama et al., *Theor. Appl. Genet.* 205:34 (1986); Part et al., *Plant Mol. Biol.* 32:1135-1148 (1996); Abedinia et al., *Aust. J. Plant Physiol.* 24:133-141 (1997); Zhang and Wu, *Theor. Appl. Genet.* 76:835 (1988); Zhang et al., *Plant Cell Rep.* 7:379 (1988); Battraw and Hall, *Plant Sci.* 86:191-202 (1992); Christou et al., *Bio/Technology* 9:957 (1991), all of which are herein incorporated by reference in their entirety); rye (De la Pena et al., *Nature* 325:274 (1987), the entirety of which is herein incorporated by reference); sugarcane (Bower and Birch, *Plant J.* 2:409 (1992), the entirety of which is herein incorporated by reference); tall fescue (Wang et al., *Bio/Technology* 10:691 (1992), the entirety of which is herein incorporated by reference) and wheat (Vasil et al., *Bio/Technology* 10:667 (1992), the entirety of which is herein incorporated by reference; U.S. Pat. No. 5,631,152, the entirety of which is herein incorporated by reference.)

Assays for gene expression based on the transient expression of cloned nucleic acid constructs have been developed by introducing the nucleic acid molecules into plant cells by polyethylene glycol treatment, electroporation, or particle bombardment (Marcotte et al., *Nature* 335:454-457 (1988), the entirety of which is herein incorporated by reference; Marcotte et al., *Plant Cell* 1:523-532 (1989), the entirety of which is herein incorporated by reference; McCarty et al., *Cell* 66:895-905 (1991), the entirety of which is herein incorporated by reference; Hattori et al., *Genes Dev.* 6:609-618 (1992), the entirety of which is herein incorporated by reference; Goff et al., *EMBO J.* 9:2517-2522 (1990), the entirety of which is herein incorporated by reference). Transient expression systems may be used to functionally dissect gene constructs (see generally, Mailga et al., *Methods in Plant Molecular Biology*, Cold Spring Harbor Press (1995)).

Any of the nucleic acid molecules of the invention may be introduced into a plant cell in a permanent or transient manner in combination with other genetic elements such as vectors, promoters, enhancers, etc. Further, any of the nucleic acid molecules of the invention may be introduced into a plant cell in a manner that allows for overexpression of the protein or fragment thereof encoded by the nucleic acid molecule.

Cosuppression is the reduction in expression levels, usually at the level of RNA, of a particular endogenous gene or gene family by the expression of a homologous sense

construct that is capable of transcribing mRNA of the same strandedness as the transcript of the endogenous gene (Napoli et al., *Plant Cell* 2:279-289 (1990), the entirety of which is herein incorporated by reference; van der Krol et al., *Plant Cell* 2:291-299 (1990), the entirety of which is herein incorporated by reference). Cosuppression may result from stable transformation with a single copy nucleic acid molecule that is homologous to a nucleic acid sequence found with the cell (Prolls and Meyer, *Plant J.* 2:465-475 (1992), the entirety of which is herein incorporated by reference) or with multiple copies of a nucleic acid molecule that is homologous to a nucleic acid sequence found with the cell (Mittlesten et al., *Mol. Gen. Genet.* 244:325-330 (1994), the entirety of which is herein incorporated by reference). Genes, even though different, linked to homologous promoters may result in the cosuppression of the linked genes (Vaucheret, *C.R. Acad. Sci. III* 316:1471-1483 (1993), the entirety of which is herein incorporated by reference).

This technique has, for example, been applied to generate white flowers from red petunia and tomatoes that do not ripen on the vine. Up to 50% of petunia transformants that contained a sense copy of the glucoamylase (CHS) gene produced white flowers or floral sectors, this was as a result of the post-transcriptional loss of mRNA encoding CHS (Flavell, *Proc. Natl. Acad. Sci. (U.S.A.)* 91:3490-3496 (1994), the entirety of which is herein incorporated by reference); van Blokland et al., *Plant J.* 6:861-877 (1994), the entirety of which is herein incorporated by reference). Cosuppression may require the coordinate transcription of the transgene and the endogenous gene and can be reset by a developmental control mechanism (Jorigensen, *Trends Biotechnol.* 8:340-344 (1990), the entirety of which is herein incorporated by reference; Meins and Kunz, In: *Gene Inactivation and Homologous Recombination in Plants*, Paszkowski (ed.), pp. 335-348, Kluwer Academic, Netherlands (1994), the entirety of which is herein incorporated by reference).

It is understood that one or more of the nucleic acids of the invention may be introduced into a plant cell and transcribed using an appropriate promoter with such transcription resulting in the cosuppression of an endogenous protein.

Antisense approaches are a way of preventing or reducing gene function by targeting the genetic material (Mol et al., *FEBS Lett.* 268:427-430 (1990), the entirety of which is herein incorporated by reference). The objective of the antisense approach is to use a sequence complementary to the target gene to block its expression and create a mutant cell line or organism in which the level of a single chosen protein is selectively reduced or abolished. Antisense techniques have several advantages over other 'reverse' genetic approaches. The site of inactivation and its developmental effect can be manipulated by the choice of promoter for antisense genes or by the timing of external application or microinjection. Antisense can manipulate its specificity by selecting either unique regions of the target gene or regions where it shares homology to other related genes (Hiatt et al., In: *Genetic Engineering*, Setlow (ed.), Vol. 11, New York: Plenum 49-63 (1989), the entirety of which is herein incorporated by reference).

The principle of regulation by antisense RNA is that RNA that is complementary to the target mRNA is introduced into cells, resulting in specific RNA:RNA duplexes being formed by base pairing between the antisense substrate and the target mRNA (Green et al., *Annu. Rev. Biochem.* 55:569-597 (1986), the entirety of which is herein incorporated by reference). Under one embodiment, the process involves the

introduction and expression of an antisense gene sequence. Such a sequence is one in which part or all of the normal gene sequences are placed under a promoter in inverted orientation so that the 'wrong' or complementary strand is transcribed into a noncoding antisense RNA that hybridizes with the target mRNA and interferes with its expression (Takayama and Inouye, *Crit. Rev. Biochem. Mol. Biol.* 25:155-184 (1990), the entirety of which is herein incorporated by reference). An antisense vector is constructed by standard procedures and introduced into cells by transformation, transfection, electroporation, microinjection, infection, etc. The type of transformation and choice of vector will determine whether expression is transient or stable. The promoter used for the antisense gene may influence the level, timing, tissue, specificity, or inducibility of the antisense inhibition.

It is understood that the activity of a protein in a plant cell may be reduced or depressed by growing a transformed plant cell containing a nucleic acid molecule of the present invention whose non-transcribed strand encodes a protein or fragment thereof.

Antibodies have been expressed in plants (Hiatt et al., *Nature* 342:76-78 (1989), the entirety of which is herein incorporated by reference; Conrad and Fielder, *Plant Mol. Biol.* 26:1023-1030 (1994), the entirety of which is herein incorporated by reference). Cytoplasmic expression of a scFv (single-chain Fv antibodies) has been reported to delay infection by artichoke mottled crinkle virus. Transgenic plants that express antibodies directed against endogenous proteins may exhibit a physiological effect (Philips et al., *EMBO J.* 16:4489-4496 (1997), the entirety of which is herein incorporated by reference; Marion-Poll, *Trends in Plant Science* 2:447-448 (1997), the entirety of which is herein incorporated by reference). For example, expressed anti-abscisic antibodies have been reported to result in a general perturbation of seed development (Philips et al., *EMBO J.* 16: 4489-4496 (1997)).

Antibodies that are catalytic may also be expressed in plants (abzymes). The principle behind abzymes is that since antibodies may be raised against many molecules, this recognition ability can be directed toward generating antibodies that bind transition states to force a chemical reaction forward (Persidas, *Nature Biotechnology* 15:1313-1315 (1997), the entirety of which is herein incorporated by reference; Baca et al., *Ann. Rev. Biophys. Biomol. Struct.* 26:461-493 (1997), the entirety of which is herein incorporated by reference). The catalytic abilities of abzymes may be enhanced by site directed mutagenesis. Examples of abzymes are, for example, set forth in U.S. Pat. Nos.: 5,658,753; 5,632,990; 5,631,137; 5,602,015; 5,559,538; 5,576,174; 5,500,358; 5,318,897; 5,298,409; 5,258,289 and 5,194,585, all of which are herein incorporated in their entirety.

It is understood that any of the antibodies of the invention may be expressed in plants and that such expression can result in a physiological effect. It is also understood that any of the expressed antibodies may be catalytic.

(d) Antibodies

One aspect of the invention concerns antibodies, single-chain antigen binding molecules, or other proteins that specifically bind to one or more of the protein or peptide molecules of the invention and their homologues, fusions or fragments. In a preferred embodiment, an antibody of the present invention binds to an amino acid selected from the group consisting of SEQ ID NO: 622 through 625. Such antibodies may be used to quantitatively or qualitatively

detect the protein or peptide molecules of the invention. As used herein, an antibody or peptide is said to "specifically bind" to a protein or peptide molecule of the invention if such binding is not competitively inhibited by the presence of non-related molecules.

Nucleic acid molecules that encode all or part of the protein of the invention can be expressed, via recombinant means, to yield protein or peptides that can in turn be used to elicit antibodies that are capable of binding the expressed protein or peptide. Such antibodies may be used in immunoassays for that protein. Such protein-encoding molecules, or their fragments may be a "fusion" molecule (i.e., a part of a larger nucleic acid molecule) such that, upon expression, a fusion protein is produced. It is understood that any of the nucleic acid molecules of the invention may be expressed, via recombinant means, to yield proteins or peptides encoded by these nucleic acid molecules.

The antibodies that specifically bind proteins and protein fragments of the invention may be polyclonal or monoclonal and may comprise intact immunoglobulins, or antigen binding portions of immunoglobulins fragments (such as F(ab)', F(ab')₂), or single-chain immunoglobulins producible, for example, via recombinant means. It is understood that practitioners are familiar with the standard resource materials which describe specific conditions and procedures for the construction, manipulation and isolation of antibodies (see, for example, Harlow and Lane, In: *Antibodies: A Laboratory Manual*, Cold Spring Harbor Press, Cold Spring Harbor, N.Y. (1988), the entirety of which is herein incorporated by reference).

Murine monoclonal antibodies are particularly preferred. BALB/c mice are preferred for this purpose, however, equivalent strains may also be used. The animals are preferably immunized with approximately 25 μ g of purified protein (or fragment thereof) that has been emulsified in a suitable adjuvant (such as TiterMax adjuvant (Vaxcel, Norcross, Ga.)). Immunization is preferably conducted at two intramuscular sites, one intraperitoneal site and one subcutaneous site at the base of the tail. An additional i.v. injection of approximately 25 μ g of antigen is preferably given in normal saline three weeks later. After approximately 11 days following the second injection, the mice may be bled and the blood screened for the presence of anti-protein or peptide antibodies. Preferably, a direct binding Enzyme-Linked Immunoassay (ELISA) is employed for this purpose.

More preferably, the mouse having the highest antibody titer is given a third i.v. injection of approximately 25 μ g of the same protein or fragment. The splenic leukocytes from this animal may be recovered 3 days later and then permitted to fuse, most preferably, using polyethylene glycol, with cells of a suitable myeloma cell line (such as, for example, the P3X63Ag8.653 myeloma cell line). Hybridoma cells are selected by culturing the cells under "HAT" (hypoxanthine-aminopterin-thymine) selection for about one week. The resulting clones may then be screened for their capacity to produce monoclonal antibodies ("mAbs"), preferably by direct ELISA.

In one embodiment, anti-protein or peptide monoclonal antibodies are isolated using a fusion of a protein or peptide of the invention, or conjugate of a protein or peptide of the invention, as immunogens. Thus, for example, a group of mice can be immunized using a fusion protein emulsified in Freund's complete adjuvant (e.g., approximately 50 μ g of antigen per immunization). At three week intervals, an identical amount of antigen is emulsified in Freund's incom-

plete adjuvant and used to immunize the animals. Ten days following the third immunization, serum samples are taken and evaluated for the presence of antibody. If antibody titers are too low, a fourth booster can be employed. Polysera capable of binding the protein or peptide can also be obtained using this method.

In a preferred procedure for obtaining monoclonal antibodies, the spleens of the above-described immunized mice are removed, disrupted and immune splenocytes are isolated over a ficoll gradient. The isolated splenocytes are fused, using polyethylene glycol with BALB/c-derived HGPRT (hypoxanthine guanine phosphoribosyl transferase) deficient P3x63xAg8.653 plasmacytoma cells. The fused cells are plated into 96 well microtiter plates and screened for hybridoma fusion cells by their capacity to row in culture medium supplemented with hypoxanthine, aminopterin and thymidine for approximately 2-3 weeks.

Hybridoma cells that arise from such incubation are preferably screened for their capacity to produce an immunoglobulin that binds to a protein of interest. An indirect ELISA may be used for this purpose. In brief, the supernatants of hybridomas are incubated in microtiter wells that contain immobilized protein. After washing, the titer of bound immunoglobulin can be determined using, for example, a goat anti-mouse antibody conjugated to horseradish peroxidase. After additional washing, the amount of immobilized enzyme is determined (for example through the use of a chromogenic substrate). Such screening is performed as quickly as possible after the identification of the hybridoma in order to ensure that a desired clone is not overgrown by non-secreting neighbor cells. Desirably, the fusion plates are screened several times since the rates of hybridoma growth vary. In a preferred sub-embodiment, a different antigenic form may be used to screen the hybridoma. Thus, for example, the splenocytes may be immunized with one immunogen, but the resulting hybridomas can be screened using a different immunogen. It is understood that any of the protein or peptide molecules of the invention may be used to raise antibodies.

As discussed below, such antibody molecules or their fragments may be used for diagnostic purposes. Where the antibodies are intended for diagnostic purposes, it may be desirable to derivatized them, for example with a ligand group (such as biotin) or a detectable marker group (such as a fluorescent group, a radioisotope or an enzyme).

The ability to produce antibodies that bind the protein or peptide molecules of the invention permits the identification of mimetic compounds derived from those molecules. These mimetic compounds may contain a fragment of the protein or peptide or merely a structurally similar region and nonetheless exhibits an ability to specifically bind to antibodies directed against that compound.

It is understood that any of the agents of the invention can be substantially purified and/or be biologically active and/or recombinant.

(e) Exemplary Uses

Nucleic acid molecules and fragments thereof of the invention may be employed to obtain other nucleic acid molecules from the same species (nucleic acid molecules from maize may be utilized to obtain other nucleic acid molecules from maize). Such nucleic acid molecules include the nucleic acid molecules that encode the complete coding sequence of a protein and promoters and flanking sequences of such molecules. In addition, such nucleic acid molecules include nucleic acid molecules that encode for other isozymes or gene family members. Such molecules can be

readily obtained by using the above-described nucleic acid molecules or fragments thereof to screen cDNA or genomic libraries. Methods for forming such libraries are well known in the art.

Nucleic acid molecules and fragments thereof of the invention may also be employed to obtain nucleic acid homologs. Such homologs include the nucleic acid molecule of other plants or other organisms (e.g., alfalfa, *Arabidopsis*, barley, Brassica, broccoli, cabbage, citrus, cotton, garlic, oat, oilseed rape, onion, canola, flax, an ornamental plant, pea, peanut, pepper, potato, rice, rye, sorghum, strawberry, sugarcane, sugarbeet, tomato, wheat, poplar, pine, fir, eucalyptus, apple, lettuce, lentils, grape, banana, tea, turf grasses, sunflower, oil palm, *Phaseolus*, etc.) including the nucleic acid molecules that encode, in whole or in part, protein homologs of other plant species or other organisms, sequences of genetic elements, such as promoters and transcriptional regulatory elements. Particularly preferred plants are selected from the group consisting of maize, canola, soybean, crambe, mustard, castor bean, peanut, sesame, cottonseed, linseed, safflower, oil palm, flax and sunflower.

Such molecules can be readily obtained by using the above-described nucleic acid molecules or fragments thereof to screen cDNA or genomic libraries obtained from such plant species. Methods for forming such libraries are well known in the art. Such homolog molecules may differ in their nucleotide sequences from those found in one or more of SEQ ID NOS: 1-4, 6-29 or complements thereof because complete complementarity is not needed for stable hybridization. The nucleic acid molecules of the invention therefore also include molecules that, although capable of specifically hybridizing with the nucleic acid molecules may lack "complete complementarity."

Any of a variety of methods may be used to obtain one or more of the above-described nucleic acid molecules (Zamechik et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 83:4143-4146 (1986); Goodchild et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 85:5507-5511 (1988); Wickstrom et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 85:1028-1032 (1988); Holt et al., *Molec. Cell. Biol.* 8:963-973 (1988); Gerwitz et al., *Science* 242:1303-1306 (1988); Anfossi et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 86:3379-3383 (1989); Becker et al., *EMBO J.* 8:3685-3691 (1989)). Automated nucleic acid synthesizers may be employed for this purpose. In lieu of such synthesis, the disclosed nucleic acid molecules may be used to define a pair of primers that can be used with the polymerase chain reaction (Mullis et al., *Cold Spring Harbor Symp. Quant. Biol.* 51:263-273 (1986); Erlich et al., European Patent 50,424; European Patent 84,796; European Patent 258,017; European Patent 237,362; Mullis, European Patent 201,184; Mullis et al., U.S. Pat. No. 4,683,202; Erlich, U.S. Pat. No. 4,582,788; and Saiki et al., U.S. Pat. No. 4,683,194) to amplify and obtain any desired nucleic acid molecule or fragment.

Promoter sequences and other Genetic elements, including but not limited to transcriptional regulatory flanking sequences, associated with one or more of the disclosed nucleic acid sequences can also be obtained using the disclosed nucleic acid sequence provided herein. In one embodiment, such sequences are obtained by incubating, nucleic acid molecules of the present invention with members of genomic libraries and recovering clones that hybridize to such nucleic acid molecules thereof. In a second embodiment, methods of "chromosome walking," or inverse PCR may be used to obtain such sequences (Frohman et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 85:8998-9002 (1988); Ohara et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 86:5673-5677 (1989);

Pang et al., *Biotechniques* 22:1046-1048 (1977); Huang et al., *Methods Mol. Biol.* 69:89-96 (1997); Huang et al., *Methods Mol. Biol.* 67:287-294 (1997); Benkel et al., *Genet. Anal.* 13:123-127 (1996); Harti et al., *Methods Mol. Biol.* 58:293-301 (1996)). The term "chromosome walking" means a process of extending a genetic map by successive hybridization steps.

The nucleic acid molecules of the invention may be used to isolate promoters of cell enhanced, cell specific, tissue enhanced, tissue specific, developmentally or environmentally regulated expression profiles. Isolation and functional analysis of the 5' flanking promoter sequences of these genes from genomic libraries, for example, using genomic screening methods and PCR techniques would result in the isolation of useful promoters and transcriptional regulatory elements. These methods are known to those of skill in the art and have been described (See, for example, Birren et al., *Genome Analysis: Analyzing DNA*, 1, (1997), Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y.). Promoters obtained utilizing the nucleic acid molecules of the invention could also be modified to affect their control characteristics. Examples of such modifications would include but are not limited to enhancer sequences. Such genetic elements could be used to enhance gene expression of new and existing traits for crop improvement.

Another subset of the nucleic acid molecules of the invention includes nucleic acid molecules that are markers. The markers can be used in a number of conventional ways in the field of molecular genetics. Such markers include nucleic acid molecules SEQ ID NOS: 1-4, 6-29 or complements thereof or fragments of either that can act as markers and other nucleic acid molecules of the present invention that can act as markers.

Genetic markers of the invention include "dominant" or "codominant" markers. "Codominant markers" reveal the presence of two or more alleles (two per diploid individual) at a locus. "Dominant markers" reveal the presence of only a single allele per locus. The presence of the dominant marker phenotype (e.g., a band of DNA) is an indication that one allele is in either the homozygous or heterozygous condition. The absence of the dominant marker phenotype (e.g., absence of a DNA band) is merely evidence that "some other" undefined allele is present. In the case of populations where individuals are predominantly homozygous and loci are predominately dimorphic, dominant and codominant markers can be equally valuable. As populations become more heterozygous and multi-allelic, codominant markers often become more informative of the genotype than dominant markers. Marker molecules can be, for example, capable of detecting polymorphisms such as single nucleotide polymorphisms (SNPs).

The genomes of animals and plants naturally undergo spontaneous mutation in the course of their continuing evolution (Gusella, *Ann. Rev. Biochem.* 55:831-854 (1986)). A "polymorphism" is a variation or difference in the sequence of the gene or its flanking regions that arises in some of the members of a species. The variant sequence and the "original" sequence co-exist in the species' population. In some instances, such co-existence is in stable or quasi-stable equilibrium.

A polymorphism is thus said to be "allelic," in that, due to the existence of the polymorphism, some members of a species may have the original sequence (i.e., the original "allele") whereas other members may have the variant sequence (i.e., the variant "allele"). In the simplest case, only one variant sequence may exist and the polymorphism

is thus said to be diallelic. In other cases, the species population may contain multiple alleles and the polymorphism is termed tri-allelic, etc. A single gene may have multiple different unrelated polymorphisms. For example, it may have a di-allelic polymorphism at one site and a multi-allelic polymorphism at another site.

The variation that defines the polymorphism may range from a single nucleotide variation to the insertion or deletion of extended regions within a gene. In some cases, the DNA sequence variations are in regions of the genome that are characterized by short tandem repeats (STRs) that include tandem di- or tri-nucleotide repeated motifs of nucleotides. Polymorphisms characterized by such tandem repeats are referred to as "variable number tandem repeat" ("VNTR") polymorphisms. VNTRs have been used in identity analysis (Weber, U.S. Pat. No. 5,075,217; Armour et al., *FEBS Lett.* 307:113-115 (1992); Jones et al., *Eur. J. Haematol.* 39:144-147 (1987); Horn et al., PCT Patent Application WO91/14003; Jeffreys, European Patent Application 370,719; Jeffreys, U.S. Pat. No. 5,175,082; Jeffreys et al., *Amer. J. Hum. Genet.* 39:11-24 (1986); Jeffreys et al., *Nature* 316:76-79 (1985); Gray et al., *Proc. R. Acad. Soc. Lond.* 24:241-253 (1991); Moore et al., *Genomics*, 10:654-660 (1991); Jeffreys et al., *Anim. Genet.* 18:1-15 (1987); Hillel et al., *Anim. Genet.* 20:145-155 (1989); Hillel et al., *Genet.* 124:783-789 (1990)).

The detection of polymorphic sites in a sample of DNA may be facilitated through the use of nucleic acid amplification methods. Such methods specifically increase the concentration of polynucleotides that span the polymorphic site, or include that site and sequences located either distal or proximal to it. Such amplified molecules can be readily detected by gel electrophoresis or other means.

In an alternative embodiment, such polymorphisms can be detected through the use of a marker nucleic acid molecule that is physically linked to such polymorphism(s). For this purpose, marker nucleic acid molecules comprising a nucleotide sequence of a polynucleotide located within 1 mb of the polymorphism(s) and more preferably within 100 kb of the polymorphism(s) and most preferably within 10 kb of the polymorphism(s) can be employed.

The identification of a polymorphism can be determined in a variety of ways. By correlating the presence or absence of it in a plant with the presence or absence of a phenotype, it is possible to predict the phenotype of that plant. If a polymorphism creates or destroys a restriction endonuclease cleavage site, or if it results in the loss or insertion of DNA (e.g., a VNTR polymorphism), it will alter the size or profile of the DNA fragments that are generated by digestion with that restriction endonuclease. As such, organisms that possess a variant sequence can be distinguished from those having the original sequence by restriction fragment analysis. Polymorphisms that can be identified in this manner are termed "restriction fragment length polymorphisms" ("RFLPs") (Glassberg, UK Patent Application 2135774; Skolnick et al., *Cytogen. Cell Genet.* 732:58-67 (1982); Botstein et al., *Anim. J. Hum. Genet.* 32:314-331 (1980); Fischer et al., (PCT Application WO90/13668; Uhlen, PCT Application WO90/11369).

Polymorphisms can also be identified by Single Strand Conformation Polymorphism (SSCP) analysis (Elles, *Methods in Molecular Medicine: Molecular Diagnosis of Genetic Diseases*, Humana Press (1996)); Orita et al., *Genomics* 5:874-879 (1989)). A number of protocols have been described for SSCP including, but not limited to, Lee et al., *Anal. Biochem.* 205:289-293 (1992); Suzuki et al., *Anal.*

Biochem. 192:82-84 (1991); Lo et al., *Nucleic Acids Research* 20:1005-1009 (1992); Sarkar et al., *Genomics* 13:441-443 (1992). It is understood that one or more of the nucleic acids of the invention, may be utilized as markers or probes to detect polymorphisms by SSCP analysis.

Polymorphisms may also be found using a DNA fingerprinting technique called amplified fragment length polymorphism (AFLP), which is based on the selective PCR amplification of restriction fragments from a total digest of genomic DNA to profile that DNA (Vos et al., *Nucleic Acids Res.* 23:4407-4414 (1995)). This method allows for the specific co-amplification of high numbers of restriction fragments, which can be visualized by PCR without knowledge of the nucleic acid sequence. It is understood that one or more of the nucleic acids of the invention may be utilized as markers or probes to detect polymorphisms by AFLP analysis or for fingerprinting RNA.

Polymorphisms may also be found using random amplified polymorphic DNA (RAPD) (Williams et al., *Nucl. Acid. Res.* 18:6531-6535 (1990)) and cleavable amplified polymorphic sequences (CAPS) (Lyamichev et al., *Science* 260:778-783 (1993)). It is understood that one or more of the nucleic acid molecules of the invention, may be utilized as markers or probes to detect polymorphisms by RAPD or CAPS analysis.

Single Nucleotide Polymorphisms (SNPs) generally occur at greater frequency than other polymorphic markers and are spaced with a greater uniformity throughout a genome than other reported forms of polymorphism. The greater frequency and uniformity of SNPs means that there is greater probability that such a polymorphism will be found near or in a genetic locus of interest than would be the case for other polymorphisms. SNPs are located in protein-coding regions and noncoding regions of a genome. Some of these SNPs may result in defective or variant protein expression (e.g., as a result of mutations or defective splicing). Analysis (genotyping) of characterized SNPs can require only a plus/minus assay rather than a lengthy measurement, permitting easier automation.

SNPs can be characterized using any of a variety of methods. Such methods include the direct or indirect sequencing of the site, the use of restriction enzymes (Botstein et al., *Am. J. Hum. Genet.* 32:314-331 (1980), the entirety of which is herein incorporated reference; Konieczny and Ausubel, *Plaint J.* 4:403-410 (1993), the entirety of which is herein incorporated by reference), enzymatic and chemical mismatch assays (Myers et al., *Nature* 313:495-498 (1985), the entirety of which is herein incorporated by reference), allele-specific PCR (Newton et al., *Nucl. Acids Res.* 17:2503-2516 (1989), the entirety of which is herein incorporated by reference; Wu et al., *Proc. Natl. Acad. Sci. USA* 86:2757-2760 (1989), the entirety of which is herein incorporated by reference), ligase chain reaction (Barany, *Proc. Natl. Acad. Sci. USA* 838:189-193 (1991), the entirety of which is herein incorporated by reference), single-strand conformation polymorphism analysis (Labruno et al., *Am. J. Hum. Genet.* 48: 1115-1120 (1991), the entirety of which is herein incorporated by reference), single base primer extension (Kuppuswamy et al., *Proc. Natl. Acad. Sci. USA* 88:1143-1147 (1991), Goelet U.S. Pat. No. 6,004,744; Goelet U.S. Pat. No. 5,888,819, all of which are herein incorporated by reference in their entirety), solid-phase ELISA-based oligonucleotide ligation assays (Nikiforov et al., *Nucl. Acids Res.* 22:4167-4175 (1994), dideoxy fingerprinting (Sarkar et al., *Genomics* 13:441-443 (1992), the entirety of which is herein incorporated by reference), oligonucleotide fluorescence-quenching assays

(Livak et al., *PCR Methods Appl.* 4:357–362 (1995a), the entirety of which is herein incorporated by reference). 5'-nuclease allele-specific hybridization TaqMan™ assay (Livak et al., *Nature Genet.* 9:341–342 (1995), the entirety of which is herein incorporated by reference), template-directed dye-terminator incorporation (TDI) assay (Chen and Kwok, *Nucl. Acids Res.* 25:347–353 (1997), the entirety of which is herein incorporated by reference), allele-specific molecular beacon assay (Tyagi et al., *Nature Biotech.* 16: 49–53 (1998), the entirety of which is herein incorporated by reference), PinPoint assay (Haff and Smirnov, *Genome Res.* 7: 378–388 (1997), the entirety of which is herein incorporated by reference), dCAPS analysis (Neff et al., *Plant J.* 14:387–392 (1998), the entirety of which is herein incorporated by reference), pyrosequencing (Ronaghi et al., *Analytical Biochemistry* 267:65–71 (1999); Ronaghi et al PCT application WO 98/13523; Nyren et al PCT application WO 98/28440, all of which are herein incorporated by reference in their entirety; <http://www.pyrosequencing.com>), using mass spectrometry, e.g., the Masscode™ system (Howbert et al WO 99/05319; Howber et al WO 97/27331, all of which are herein incorporated by reference in their entirety; <http://www.rapigene.com>; Becker et al PCT application WO 98/26095; Becker et al PCT application; WO 98/12355; Becker et al PCT application WO 97/33000; Monforte et al U.S. Pat. No. 5,965,363, all of which are herein incorporated by reference in their entirety), invasive cleavage of oligonucleotide probes (Lyamichev et al *Nature Biotechnology* 17:292–296, herein incorporated by reference in its entirety; <http://www.twt.com>), and using high density oligonucleotide arrays (Hacia et al *Nature Genetics* 22:164–167; herein incorporated by reference in its entirety; <http://www.affymetrix.com>).

Polymorphisms may also be detected using allele-specific oligonucleotides (ASO), which, can be for example, used in combination with hybridization based technology including southern, northern, and dot blot hybridizations, reverse dot blot hybridizations and hybridizations performed on microarray and related technology.

The stringency of hybridization for polymorphism detection is highly dependent upon a variety of factors, including length of the allele-specific oligonucleotide, sequence composition, degree of complementarity (i.e. presence or absence of base mismatches), concentration of salts and other factors such as formamide, and temperature. These factors are important both during the hybridization itself and during subsequent washes performed to remove target polynucleotide that is not specifically hybridized. In practice, the conditions of the final, most stringent wash are most critical. In addition, the amount of target polynucleotide that is able to hybridize to the allele-specific oligonucleotide is also governed by such factors as the concentration of both the ASO and the target polynucleotide, the presence and concentration of factors that act to “tie up” water molecules, so as to effectively concentrate the reagents (e.g., PEG, dextran, dextran sulfate, etc.), whether the nucleic acids are immobilized or in solution, and the duration of hybridization and washing steps.

Hybridizations are preferably performed below the melting temperature (T_m) of the ASO. The closer the hybridization and/or washing step is to the T_m , the higher the stringency. T_m for an oligonucleotide may be approximated, for example, according to the following formula: $T_m = 81.5 + 16.6 \times (\log_{10}[\text{Na}^+]) + 0.41 \times (\%G+C) - 675/n$; where $[\text{Na}^+]$ is the molar salt concentration of Na^+ or any other suitable cation and n =number of bases in the oligonucleotide. Other formulas for approximating T_m are available and are known to those of ordinary skill in the art.

Stringency is preferably adjusted so as to allow a given ASO to differentially hybridize to a target polynucleotide of the correct allele and a target polynucleotide of the incorrect allele. Preferably, there will be at least a two-fold differential between the signal produced by the ASO hybridizing to a target polynucleotide of the correct allele and the level of the signal produced by the ASO cross-hybridizing to a target polynucleotide of the incorrect allele (e.g., an ASO specific for a mutant allele cross-hybridizing to a wild-type allele). In more preferred embodiments of the present invention, there is at least a five-fold signal differential. In highly preferred embodiments of the present invention, there is at least an order of magnitude signal differential between the ASO hybridizing to a target polynucleotide of the correct allele and the level of the signal produced by the ASO cross-hybridizing to a target polynucleotide of the incorrect allele.

While certain methods for detecting polymorphisms are described herein, other detection methodologies may be utilized. For example, additional methodologies are known and set forth, in Birren et al., *Genome Analysis*. 4:135–186. *A Laboratory Manual, Mapping Genomes*, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y. (1999); Maliga et al., *Methods in Plant Molecular Biology: A Laboratory Course Manual*, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y. (1995); Paterson, *Biotechnology Intelligence Unit: Genome Mapping in Plants*, R. G. Landes Co., Georgetown, Tex., and Academic Press, San Diego, Calif. (1996); *The Maize Handbook*, Freeling and Walbot, eds., Springer-Verlag, New York, N.Y. (1994); *Methods in Molecular Medicine: Molecular Diagnosis of Genetic Diseases*, Elles, ed., Humana Press, Totowa, N.J. (1996); Clark, ed., *Plant Molecular Biology: A Laboratory Manual*, Clark, ed., Springer-Verlag, Berlin, Germany (1997), all of which are herein incorporated by reference in their entirety.

Requirements for marker-assisted selection in a plant breeding program are: (1) the marker(s) should co-segregate or be closely linked with the desired trait; (2) an efficient means of screening large populations for the molecular marker(s) should be available; and (3) the screening technique should have high reproducibility across laboratories and preferably be economical to use and be user-friendly.

The genetic linkage of marker molecules can be established by a gene mapping model such as, without limitation, the flanking marker model reported by Lander and Botstein, *Genetics* 121:185–199 (1989) and the interval mapping, based on maximum likelihood methods described by Lander and Botstein, *Genetics* 121:185–199 (1989) and implemented in the software package MAPMAKER/QTL (Lincoln and Lander, *Mapping Genes Controlling Quantitative Traits Using MAPMAKER/QTL*, Whitehead Institute for Biomedical Research, Massachusetts, (1990). Additional software includes Qgene, Version 2.23 (1996), Department of Plant Breeding and Biometry, 266 Emerson Hall, Cornell University, Ithaca, N.Y.). Use of Qgene software is a particularly preferred approach.

A maximum likelihood estimate (MLE) for the presence of a marker is calculated, together with an MLE assuming no QTL effect, to avoid false positives. A \log_{10} of an odds ratio (LOD) is then calculated as: $\text{LOD} = \log_{10}(\text{MLE for the presence of a QTL/MLE given no linked QTL})$.

The LOD score essentially indicates how much more likely the data are to have arisen assuming the presence of a QTL than in its absence. The LOD threshold value for avoiding a false positive with a given confidence, say 95%,

depends on the number of markers and the length of the genome. Graphs indicating LOD thresholds are set forth in Lander and Botstein, *Genetics* 121:185–199 (1989) and further described by Arús and Moreno-González, *Plant Breeding*, Hayward et al., (eds.) Chapman & Hall, London, pp. 314–331 (1993).

In a preferred embodiment of the present invention the nucleic acid marker exhibits a LOD score of greater than 2.0, more preferably 2.5, even more preferably greater than 3.0 or 4.0 with the trait or phenotype of interest. In a preferred embodiment, the trait of interest is altered, preferably increased phytosterol levels or compositions.

Additional models can be used. Many modifications and alternative approaches to interval mapping have been reported, including the use non-parametric methods (Kruglyak and Lander, *Genetics* 139:1421–1428 (1995)). Multiple regression methods or models can be also be used, in which the trait is regressed on a large number of markers (Jansen, *Biometrics in Plant Breeding*, van Oijen and Jansen (eds.), Proceedings of the Ninth Meeting of the Eucarpia Section Biometrics in Plant Breeding, The Netherlands, pp. 116–124 (1994), Weber and Wricke, *Advances in Plant Breeding*, Blackwell, Berlin, 16 (1994)). Procedures combining interval mapping with regression analysis, whereby the phenotype is regressed onto a single putative QTL at a given marker interval and at the same time onto a number of markers that serve as cofactors, have been reported by Jansen and Stam, *Genetics* 16:1447–1455 (1994), and Zeng, *Genetics* 136:1457–1468 (1994). Generally, the use of cofactors reduces the bias and sampling error of the estimated QTL positions (Utz and Melchinger, *Biometrics in Plant Breeding*, van Oijen and Jansen (eds.) Proceedings of the Ninth Meeting of the Eucarpia Section Biometrics in Plant Breeding, The Netherlands, pp. 195–204 (1994), thereby improving the precision and efficiency of QTL mapping (Zeng, *Genetics* 136:1457–1468 (1994), herein incorporated by reference in its entirety). These models can be extended to multi-environment experiments to analyze genotype-environment interactions (Jansen et al., *Theo. Appl. Genet.* 91:33–37 (1995), herein incorporated by reference in its entirety).

It is understood that one or more of the nucleic acid molecules of the invention may be used as molecular markers. It is also understood that one or more of the protein molecules of the invention may be used as molecular markers.

In a preferred embodiment, the polymorphism is present and screened for in a mapping population, e.g., a collection of plants capable of being used with markers such as polymorphic markers to map genetic position of traits. The choice of appropriate mapping population often depends on the type of marker systems employed (Tanksley et al., *J. P. Gustafson and R. Appels* (eds.). Plenum Press, New York, pp. 157–173 (1988), the entirety of which is herein incorporated by reference). Consideration must be given to the source of parents (adapted vs. exotic) used in the mapping population. Chromosome pairing and recombination rates can be severely disturbed (suppressed) in wide crosses (adapted x exotic) and generally yield greatly reduced linkage distances. Wide crosses will usually provide segregating populations with a relatively large number of polymorphisms when compared to progeny in a narrow cross (adapted x adapted).

An F_2 population is the first generation of selfing (self-pollinating) after the hybrid seed is produced. Usually a single F_1 plant is selfed to generate a population segregating

for all the genes in Mendelian (1:2:1) pattern. Maximum genetic information is obtained from a completely classified F_2 population using a codominant marker system (Mather, Measurement of Linkage in Heredity: Methuen and Co., (1938), the entirety of which is herein incorporated by reference). In the case of dominant markers, progeny tests (e.g., F_3 BCF $_2$) are required to identify the heterozygotes, in order to classify the population. However, this procedure is often prohibitive because of the cost and time involved in progeny testing. Progeny testing of F_2 individuals is often used in map construction where phenotypes do not consistently reflect genotype (e.g. disease resistance) or where trait expression is controlled by a QTL. Segregation data from progeny test populations e.g. F_3 or BCF $_2$) can be used in map construction. Marker-assisted selection can then be applied to cross progeny based on marker-trait map associations (F_2 , F_3), where linkage groups have not been completely disassociated by recombination events (i.e., maximum disequilibrium).

Recombinant inbred lines (RIL) (genetically related lines; usually $>F_5$, developed from continuously selfing F_2 lines towards homozygosity) can be used as a mapping population. Information obtained from dominant markers can be maximized by using RIL because all loci are homozygous or nearly so. Under conditions of tight linkage (i.e. about <10% recombination), dominant and co-dominant markers evaluated in RIL populations provide more information per individual than either marker type in backcross populations (Reiter, *Proc. Natl. Acad. Sci. (U.S.A.)* 89:1477–1481 (1992), the entirety of which is herein incorporated by reference). However, as the distance between markers becomes larger (i.e., loci become more independent), the information in RIL populations decreases dramatically when compared to codominant markers.

Backcross populations (e.g., generated from a cross between a successful variety (recurrent parent) and another variety (donor parent) carrying a trait not present in the former) can be utilized as a mapping population. A series of backcrosses to the recurrent parent can be made to recover most of its desirable traits. Thus a population is created consisting of individuals nearly like the recurrent parent but each individual carries varying amounts or mosaic of genomic regions from the donor parent. Backcross populations can be useful for mapping dominant markers if all loci in the recurrent parent are homozygous and the donor and recurrent parent have contrasting polymorphic marker alleles (Reiter et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 89:1477–1481 (1992), the entirety of which is herein incorporated by reference). Information obtained from backcross populations using either codominant or dominant markers is less than that obtained from F_2 populations because one, rather than two, recombinant gamete is sampled per plant. Backcross populations, however, are more informative (at low marker saturation) when compared to RILs as the distance between linked loci increases in RIL populations (i.e. about 0.15% recombination). Increased recombination can be beneficial for resolution of tight linkages, but may be undesirable in the construction of maps with low marker saturation.

Near-isogenic lines (NIL) (created by many backcrosses to produce a collection of individuals that is nearly identical in genetic composition except for the trait or genomic region under interrogation) can be used as a mapping population. In mapping with NILs, only a portion of the polymorphic loci is expected to map to a selected region.

Bulk segregant analysis (BSA) is a method developed for the rapid identification of linkage between markers and traits

of interest (Michelmore et al., *Proc. Natl. Acad. Sci. U.S.A.* 88:9828–9832 (1991), the entirety of which is herein incorporated by reference). In BSA, two bulked DNA samples are drawn from a segregating population originating from a single cross. These bulks contain individuals that are identical for a particular trait (resistant or susceptible to particular disease) or genomic region but arbitrary at unlinked regions (i.e. heterozygous). Regions unlinked to the target region will not differ between the bulked samples of many individuals in BSA.

In an aspect of the present invention, one or more of the nucleic molecules of the present invention are used to determine the level (i.e., the concentration of mRNA in a sample, etc.) in a plant (preferably maize, canola, soybean, crambe, mustard, castor bean, peanut, sesame, cottonseed, linseed, safflower, oil palm, flax or sunflower) or pattern (i.e., the kinetics of expression, rate of decomposition, stability profile, etc.) of the expression of a protein encoded in part or whole by one or more of the nucleic acid molecule of the present invention (collectively, the “Expression Response” of a cell or tissue).

As used herein, the Expression Response manifested by a cell or tissue is said to be “altered” if it differs from the Expression Response of cells or tissues of plants not exhibiting the phenotype. To determine whether a Expression Response is altered, the Expression Response manifested by the cell or tissue of the plant exhibiting the phenotype is compared with that of a similar cell or tissue sample of a plant not exhibiting the phenotype. As will be appreciated, it is not necessary to re-determine the Expression Response of the cell or tissue sample of plants not exhibiting the phenotype each time such a comparison is made, rather, the Expression Response of a particular plant may be compared with previously obtained values of normal plants. As used herein, the phenotype of the organism is an of one or more characteristics of an organism (e.g. disease resistance, pest tolerance, environmental tolerance such as tolerance to abiotic stress, male sterility, quality improvement or yield etc.). A change in genotype or phenotype may be transient or permanent. Also as used herein, a tissue sample is any sample that comprises more than one cell. In a preferred aspect, a tissue sample comprises cells that share a common characteristic (e.g. derived from root, seed, flower, leaf, stem or pollen etc.).

In one aspect of the present invention, an evaluation can be conducted to determine whether a particular mRNA molecule is present. One or more of the nucleic acid molecules of the present invention are utilized to detect the presence or quantity of the mRNA species. Such molecules are then incubated with cell or tissue extracts of a plant under conditions sufficient to permit nucleic acid hybridization. The detection of double-stranded probe-mRNA hybrid molecules is indicative of the presence of the mRNA; the amount of such hybrid formed is proportional to the amount of mRNA. Thus, such probes may be used to ascertain the level and extent of the mRNA production in a plant’s cells or tissues. Such nucleic acid hybridization may be conducted under quantitative conditions (thereby providing a numerical value of the amount of the mRNA present). Alternatively, the assay may be conducted as a qualitative assay that indicates either that the mRNA is present, or that its level exceeds a user set, predefined value.

A number of methods can be used to compare the expression response between two or more samples of cells or tissue. These methods include hybridization assays, such as northern. RNase protection assays, and in situ hybridization. Alternatively, the methods include PCR-type assays. In

a preferred method, the expression response is compared by hybridizing nucleic acids from the two or more samples to an array of nucleic acids. The array contains a plurality of suspected sequences known or suspected of being present in the cells or tissue of the samples.

An advantage of in situ hybridization over more conventional techniques for the detection of nucleic acids is that it allows an investigator to determine the precise spatial population (Angerer et al., *Dev. Biol.* 101:477–484 (1984); Angerer et al., *Dev. Biol.* 112:157–166 (1985); Dixon et al., *EMBO* 10:1317–1324 (1991)). In situ hybridization may be used to measure the steady-state level of RNA accumulation (Hardin et al., *J. Mol. Biol.* 202:417–431 (1989)). A number of protocols have been devised for in situ hybridization, each with tissue preparation, hybridization and washing conditions (Meyerowitz, *Plant Mol. Biol. Rep.* 5:242–250 (1987); Cox and Goldberg. In: *Plant Molecular Biology: A Practical Approach*, Shaw (ed.), pp. 1–35, IRL Press, Oxford (1988); Raikhel et al., *In situ RNA hybridization in plant tissues*, In: *Plant Molecular Biology Manual*, vol. B9:1–32, Kluwer Academic Publisher, Dordrecht, Belgium (1989)).

In situ hybridization also allows for the localization of proteins within a tissue or cell (Wilkinson, *In situ Hybridization*, Oxford University Press, Oxford (1992); Langdale, *In situ Hybridization In: The Maize Handbook*, Freeling and Walbot (eds.), pp. 165–179, Springer-Verlag, New York (1994)). It is understood that one or more of the molecules of the invention, preferably one or more of the nucleic acid molecules or fragments thereof of the invention or one or more of the antibodies of the invention may be utilized to detect the level or pattern of a protein or mRNA thereof by in situ hybridization.

Fluorescent in situ hybridization allows the localization of a particular DNA sequence along a chromosome, which is useful, among other uses, for gene mapping, following chromosomes in hybrid lines, or detecting chromosomes with translocations, transversions or deletions. In situ hybridization has been used to identify chromosomes in several plant species (Griffor et al., *Plant Mol. Biol.* 17:101–109 (1991); Gustafson et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 87:1899–1902 (1990); Mukai and Gill, *Genome* 34:448–452 (1991); Schwarzacher and Heslop-Harrison, *Genome* 34:317–323 (1991); Wang et al., *Jpn. J. Genet.* 66:313–316 (1991); Parra and Windle, *Nature Genetics* 5:17–21 (1993)). It is understood that the nucleic acid molecules of the invention may be used as probes or markers to localize sequences along a chromosome.

Another method to localize the expression of a molecule is tissue printing. Tissue printing provides a way to screen, at the same time on the same membrane many tissue sections from different plants or different developmental stages (Yomo and Taylor, *Planta* 112:35–43 (1973); Harris and Chrispeels, *Plant Physiol.* 56:292–299 (1975); Cassab and Varner, *J. Cell. Biol.* 105:2581–2588 (1987); Spruce et al., *Phytochemistry* 26:2901–2903 (1987); Barres et al., *Neuron* 5:527–544 (1990); Reid and Pont-Lezica, *Tissue Printing: Tools for the Study of Anatomy, Histochemistry and Gene Expression*, Academic Press, New York, N.Y. (1992); Reid et al., *Plant Physiol.* 93:160–165 (1990); Ye et al., *Plant J.* 1:175–183 (1991)).

A microarray-based method for high-throughput monitoring of gene expression may be utilized to measure expression response. This ‘chip’-based approach involves microarrays of nucleic acid molecules as gene-specific hybridization targets to quantitatively measure expression of the corresponding mRNA (Schena et al., *Science* 270:467–470

(1995), the entirety of which is herein incorporated by reference; <http://cmgm.stanford.edu/pbrown/array.html>; Shalon, Ph.D. Thesis, Stanford University (1996), the entirety of which is herein incorporated by reference). Hybridization to a microarray can be used to efficiently analyze the presence and/or amount of a number of nucleotide sequences simultaneously.

Several microarray methods have been described. One method compares the sequences to be analyzed by hybridization to a set of oligonucleotides representing all possible subsequences (Bains and Smith, *J. Theor. Biol.* 135:303-307 (1989), the entirety of which is herein incorporated by reference). A second method hybridizes the sample to an array of oligonucleotide or cDNA molecules. An array consisting of oligonucleotides complementary to subsequences of a target sequence can be used to determine the identity of a target sequence, measure its amount, and detect single nucleotide differences between the target and a reference sequence. Nucleic acid molecule microarrays may also be screened with protein molecules or fragments thereof to determine nucleic acid molecules that specifically bind protein molecules or fragments thereof.

The microarray approach may be used with polypeptide targets (U.S. Pat. Nos. 5,445,934; 5,143,854; 5,079,600; 4,923,901, all of which are herein incorporated by reference in their entirety). Essentially polypeptides are synthesized on a substrate (microarray) and these polypeptides can be screened with either protein molecules or fragments thereof or nucleic acid molecules in order to screen for either protein molecules or fragments thereof or nucleic acid molecules that specifically bind the target polypeptides. (Fodor et al., *Science* 251:767-773 (1991), the entirety of which is herein incorporated by reference). It is understood that one or more of the nucleic acid molecules or protein or fragments thereof of the invention may be utilized in a microarray-based method.

In a preferred embodiment of the present invention microarrays may be prepared that comprise nucleic acid molecules where preferably at least 10%, preferably at least 25%, more preferably at least 50% and even more preferably at least 75%, 80%, 85%, 90% or 95% of the nucleic acid molecules located on that array are selected from the group of nucleic acid molecules that specifically hybridize to one or more nucleic acid molecule having a nucleic acid sequence selected from the group of SEQ ID NO: 1 through SEQ ID NO: 621 or complements thereof or fragments of either.

In another preferred embodiment of the present invention microarrays may be prepared that comprise nucleic acid molecules where preferably at least 10%, preferably at least 25%, more preferably at least 50% and even more preferably at least 75%, 80%, 85%, 90% or 95% of the nucleic acid molecules located on that array are selected from the group of nucleic acid molecules having a nucleic acid sequence selected from the group of SEQ ID NO: 1 through SEQ ID NO: 621 or complements thereof or fragments of either.

In a preferred embodiment of the present invention microarrays may be prepared that comprise nucleic acid molecules where such nucleic acid molecules encode at least one, preferably at least two, more preferably at least three, even more preferably at least four, five or six proteins or fragments thereof selected from the group consisting of HES1, HMGC_oA reductase, squalene synthase, cycloartenol synthase, SMTIII and UPC2. In even more preferred embodiment of the present invention microarrays may be prepared that comprise nucleic acid molecules where such nucleic

acid molecules encode at least one, preferably at least two, more preferably at least three, even more preferably at least four, five or six proteins or fragments thereof selected from the group consisting of a fungal, more preferably a yeast HES 1, a plant, more preferably a maize, soybean or Arabidopsis HES1, a plant, more preferably a rubber or an Arabidopsis HMGC_oA reductase, a plant, more preferably an Arabidopsis squalene synthase, a plant, more preferably an Arabidopsis cycloartenol synthase, a plant, more preferably an Arabidopsis SMTIII and a fungus, more preferably an yeast UPC2.

Site directed mutagenesis may be utilized to modify nucleic acid sequences, particularly as it is a technique that allows one or more of the amino acids encoded by a nucleic acid molecule to be altered (e.g., a threonine to be replaced by a methionine). At least three basic methods for site directed mutagenesis can be employed. These are cassette mutagenesis (Wells et al., *Gene* 34:315-323 (1985), the entirety of which is herein incorporated by reference), primer extension (Gilliam et al., *Gene* 12:129-137 (1980), the entirety of which is herein incorporated by reference; Zoller and Smith, *Methods Enzymol.* 100:468-500 (1983), the entirety of which is herein incorporated by reference; Dalbadie-McFarland et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 79:6409-6413 (1982), the entirety of which is herein incorporated by reference) and methods based upon PCR (Scharf et al., *Science* 233:1076-1078 (1986), the entirety of which is herein incorporated by reference; Higuchi et al., *Nucleic Acids Res.* 16:7351-7367 (1988), the entirety of which is herein incorporated by reference). Site directed mutagenesis approaches are also described in U.S. Pat. No. 5,811,238, European Patent 0 385 962, the entirety of which is herein incorporated by reference; European Patent 0 359 472, the entirety of which is herein incorporated by reference; and PCT Patent Application WO 93/07278, the entirety of which is herein incorporated by reference.

Site directed mutagenesis strategies have been applied to plants for both in vitro, as well as in vivo site directed mutagenesis (Lanz et al., *J. Biol. Chem.* 266:9971-9976 (1991), the entirety of which is herein incorporated by reference; Kovgan and Zhdanov, *Biotechnologiya* 5:148-154, No. 207160n. Chemical Abstracts 110:225 (1989), the entirety of which is herein incorporated by reference; Ge et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 86:4037-4041 (1989), the entirety of which is herein incorporated by reference; Zhu et al., *J. Biol. Chem.* 271:18494-18498 (1996), the entirety of which is herein incorporated by reference; Chu et al., *Biochemistry* 33:6150-6157 (1994), the entirety of which is herein incorporated by reference; Small et al., *EMBO J.* 11:1291-1296 (1992), the entirety of which is herein incorporated by reference; Cho et al., *Mol. Biotechnol.* 8:13-16 (1997), the entirety of which is herein incorporated by reference; Kita et al., *J. Biol. Chem.* 271:26529-26535 (1996), the entirety of which is herein incorporated by reference; Jin et al., *Mol. Microbiol.* 7:555-562 (1993), the entirety of which is herein incorporated by reference; Hatfield and Vierstra, *J. Biol. Chem.* 267:14799-14803 (1992), the entirety of which is herein incorporated by reference; Zhao et al., *Biochemistry* 31:5093-5099 (1992), the entirety of which is herein incorporated by reference).

Any of the nucleic acid molecules of the invention may either be modified by site directed mutagenesis or used as, for example, nucleic acid molecules that are used to target other nucleic acid molecules for modification. It is understood that mutants with more than one altered nucleotide can be constructed using techniques that practitioners are famil-

lar with, such as isolating restriction fragments and ligating such fragments into an expression vector (see, for example, Sambrook et al., *Molecular Cloning: A Laboratory Manual*, Cold Spring Harbor Press (1989)).

Sequence-specific DNA-binding proteins play a role in the regulation of transcription. The isolation of recombinant cDNAs encoding these proteins facilitates the biochemical analysis of their structural and functional properties. Genes encoding such DNA-binding proteins have been isolated using classical genetics (Vollbrecht et al., *Nature* 350: 241-243 (1991), the entirety of which is herein incorporated by reference) and molecular biochemical approaches, including the screening of recombinant cDNA libraries with antibodies (Landschulz et al., *Genes Dev.* 2:786-800 (1988), the entirety of which is herein incorporated by reference) or DNA probes (Bodner et al., *Cell* 55:505-518 (1988), the entirety of which is herein incorporated by reference). In addition, an in situ screening procedure has been used and has facilitated the isolation of sequence-specific DNA-binding proteins from various plant species (Gilmartin et al., *Plant Cell* 4:839-849 (1992), the entirety of which is herein incorporated by reference; Schindler et al., *EMBO J.* 11:1261-1273 (1992), the entirety of which is herein incorporated by reference). An in situ screening protocol does not require the purification of the protein of interest (Vinson et al., *Genes Dev.* 2:801-806 (1988), the entirety of which is herein incorporated by reference, Singh et al., *Cell* 52:415-423 (1988), the entirety of which is herein incorporated by reference).

Two steps may be employed to characterize DNA-protein interactions. The first is to identify sequence fragments that interact with DNA-binding proteins, to titrate binding activity, to determine the specificity of binding and to determine whether a given DNA-binding activity can interact with related DNA sequences (Sambrook et al., *Molecular Cloning: A Laboratory Manual*, 2nd edition, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y. (1989)). Electrophoretic mobility-shift assay is a widely used assay. The assay provides a rapid and sensitive method for detecting DNA-binding proteins based on the observation that the mobility of a DNA fragment through a nondenaturing, low-ionic strength polyacrylamide gel is retarded upon association with a DNA-binding protein (Fried and Crother, *Nucleic Acids Res.* 9:6505-6525 (1981), the entirety of which is herein incorporated by reference). When one or more specific binding activities have been identified, the exact sequence of the DNA bound by the protein may be determined.

Several procedures for characterizing protein/DNA-binding sites are used, including methylation and ethylation interference assays (Maxam and Gilbert, *Methods Enzymol.* 65:499-560 (1980), the entirety of which is herein incorporated by reference; Wissman and Hillen, *Methods Enzymol.* 208:365-379 (1991), the entirety of which is herein incorporated by reference), footprinting techniques employing DNase I (Galas and Schmitz, *Nucleic Acids Res.* 5:3157-3170 (1978), the entirety of which is herein incorporated by reference), 1,10-phenanthroline-copper ion methods (Sigman et al., *Methods Enzymol.* 208:414-433 (1991), the entirety of which is herein incorporated by reference) and hydroxyl radicals methods (Dixon et al., *Methods Enzymol.* 208:414-433 (1991), the entirety of which is herein incorporated by reference). It is understood that one or more of the nucleic acid molecules of the invention may be utilized to identify a protein or fragment thereof that specifically binds to a nucleic acid molecule of the invention. It is also understood that one or more of the

protein molecules or fragments thereof of the invention may be utilized to identify a nucleic acid molecule that specifically binds to it.

A two-hybrid system is based on the fact that proteins, such as transcription factors that interact (physically) with one another carry out many cellular functions. Two-hybrid systems have been used to probe the function of new proteins (Chien et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 88:9578-9582 (1991) the entirety of which is herein incorporated by reference; Durfee et al., *Genes Dev.* 7:555-569 (1993) the entirety of which is herein incorporated by reference; Choi et al., *Cell* 78:499-512 (1994), the entirety of which is herein incorporated by reference; Kranz et al., *Genes Dev.* 8:313-327 (1994), the entirety of which is herein incorporated by reference).

Interaction mating techniques have facilitated a number of two-hybrid studies of protein-protein interaction. Interaction mating has been used to examine interactions between small sets of tens of proteins (Finley and Brent, *Proc. Natl. Acad. Sci. (U.S.A.)* 91:12098-12984 (1994), the entirety of which is herein incorporated by reference), larger sets of hundreds of proteins (Bendixen et al., *Nucl. Acids Res.* 22:1778-1779 (1994), the entirety of which is herein incorporated by reference) and to comprehensively map proteins encoded by a small genome (Bartel et al., *Nature Genetics* 12:72-77 (1996), the entirety of which is herein incorporated by reference). This technique utilizes proteins fused to the DNA-binding domain and proteins fused to the activation domain. They are expressed in two different haploid yeast strains of opposite mating type and the strains are mated to determine if the two proteins interact. Mating occurs when haploid yeast strains come into contact and result in the fusion of the two haploids into a diploid yeast strain. An interaction can be determined by the activation of a two-hybrid reporter gene in the diploid strain.

The CLONTECH laboratories, Inc. provides the MATCHMAKER two-hybrid System kit (Cat. No. K1605-1) in which the sequences encoding the two functional domains of the GAL4 transcriptional activator, DNA binding domain and activation domain, are cloned into two different shuttle/expression vectors (pGBT9 and pGAD424) (Bartel et al. In *Cellular Interactions in Development: A Practical Approach*. D. A. Hartley, ed., Oxford University Press, Oxford 153-179 (1993), the entirety of which is herein incorporated by reference). The gene code for the target protein is cloned into the pGBT9 to generate a hybrid of GAL4-DNA binding domain with a target protein and the gene(s) encode for potentially interacting protein(s) are cloned into the pGAD424 to create hybrid protein(s) of GAL4-activation domain with potentially interacting protein or with a collection of random proteins in a fusion library. The both plasmids carrying hybrid proteins are cotransformed into one yeast strain. Both hybrid proteins are targeted to the yeast nucleus by nuclear localization signal. If the target protein and the potentially interacting protein interact with each other, the GAL4 DNA binding domain and the GAL4 activation domain are brought to proximity and proper function of the transcriptional activator unit will be reconstituted resulting in transcription of reporter gene (lacZ or HIS3). An advantage of this technique is that it reduces the number of yeast transformations needed to test individual interactions. It is understood that the protein-protein interactions of protein or fragments thereof of the invention may be investigated using the two-hybrid system and that any of the nucleic acid molecules of the invention that encode such proteins or fragments thereof may be used to transform yeast in the two-hybrid system.

(f) Fungal Constructs and Fungal Transformants

The invention also relates to a fungal recombinant vector comprising exogenous genetic material. The invention also relates to a fungal cell comprising a fungal recombinant vector. The invention also relates to methods for obtaining a recombinant fungal host cell comprising introducing into a fungal host cell exogenous genetic material.

Exogenous genetic material may be transferred into a fungal cell. In a preferred embodiment the exogenous genetic material includes a nucleic acid molecule of the present invention, preferably a nucleic acid molecule having a sequence selected from the group consisting of SEQ ID NO: 1 through SEQ ID NO: 621 or complements thereof or fragments of either. Another preferred class of exogenous genetic material are nucleic acid molecules that encode a protein having an amino acid selected from the group consisting of SEQ ID NO. 622 through SEQ ID NO: 626 or fragments thereof.

The fungal recombinant vector may be any vector which can be conveniently subjected to recombinant DNA procedures. The choice of a vector will typically depend on the compatibility of the vector with the fungal host cell into which the vector is to be introduced. The vector may be a linear or a closed circular plasmid. The vector system may be a single vector or plasmid or two or more vectors or plasmids which together contain the total DNA to be introduced into the genome of the fungal host.

The fungal vector may be an autonomously replicating vector, i.e., a vector which exists as an extrachromosomal entity, the replication of which is independent of chromosomal replication, e.g., a plasmid, an extrachromosomal element, a minichromosome, or an artificial chromosome. The vector may contain any means for assuring self-replication. Alternatively, the vector may be one which, when introduced into the fungal cell, is integrated into the genome and replicated together with the chromosome(s) into which it has been integrated. This integration may be the result of homologous or non-homologous recombination.

Integration of a vector or nucleic acid into the genome by homologous recombination, regardless of the host being considered, relies on the nucleic acid sequence of the vector. Typically, the vector contains nucleic acid sequences for directing integration by homologous recombination into the genome of the host. These nucleic acid sequences enable the vector to be integrated into the host cell genome at a precise location or locations in one or more chromosomes. To increase the likelihood of integration at a precise location, there should be preferably two nucleic acid sequences that individually contain a sufficient number of nucleic acids, preferably 400 bp to 1500 bp, more preferably 800 bp to 1000 bp, which are highly homologous with the corresponding host cell target sequence. This enhances the probability of homologous recombination. These nucleic acid sequences may be any sequence that is homologous with a host cell target sequence and, furthermore, may or may not encode proteins.

For autonomous replication, the vector may further comprise an origin of replication enabling the vector to replicate autonomously, in the host cell in question. Examples of origin of replications for use in a yeast host cell are the 2 micron origin of replication and the combination of CEN3 and ARS 1. Any origin of replication may be used which is compatible with the fungal host cell of choice.

The fungal vectors of the invention preferably contain one or more selectable markers which permit easy selection of transformed cells. A selectable marker is a gene the product

of which provides, for example biocide or viral resistance, resistance to heavy metals, prototrophy to auxotrophs and the like. The selectable marker may be selected from the group including, but not limited to, *amdS* (acetamidase), *argB* (ornithine carbamoyltransferase), *bar* (phosphinothricin acetyltransferase), *hygB* (hygromycin phosphotransferase), *niaD* (nitrate reductase), *pyrG* (orotidine-5'-phosphate decarboxylase) and *sC* (sulfate adenylyltransferase) and *trpC* (anthranilate synthase). Preferred for use in an *Aspergillus* cell are the *amdS* and *pyrG* markers of *Aspergillus nidulans* or *Aspergillus oryzae* and the *bar* marker of *Streptomyces hygroscopicus*. Furthermore, selection may be accomplished by co-transformation, e.g., as described in WO 91/17243, the entirety of which is herein incorporated by reference. A nucleic acid sequence of the invention may be operably linked to a suitable promoter sequence. The promoter sequence is a nucleic acid sequence which is recognized by the fungal host cell for expression of the nucleic acid sequence. The promoter sequence contains transcription and translation control sequences which mediate the expression of the protein or fragment thereof.

A promoter may be any nucleic acid sequence which shows transcriptional activity in the fungal host cell of choice and may be obtained from genes encoding polypeptides either homologous or heterologous to the host cell. Examples of suitable promoters for directing the transcription of a nucleic acid construct of the invention in a filamentous fungal host are promoters obtained from the genes encoding *Aspergillus oryzae* TAKA amylase, *Rhizomucor miehei* aspartic proteinase, *Aspergillus niger* neutral alpha-amylase, *Aspergillus niger* acid stable alpha-amylase, *Aspergillus niger* or *Aspergillus awamori* glucoamylase (*glaA*), *Rhizomucor miehei* lipase, *Aspergillus oryzae* alkaline protease, *Aspergillus oryzae* triose phosphate isomerase, *Aspergillus nidulans* acetamidase and hybrids thereof. In a yeast host, a useful promoter is the *Saccharomyces cerevisiae* *eno-1* promoter. Particularly preferred promoters are the TAKA amylase, NA2-tpi (a hybrid of the promoters from the genes encoding *Aspergillus niger* neutral alpha-amylase and *Aspergillus oryzae* triose phosphate isomerase), *glaA*, *Saccharomyces cerevisiae* GAL1 (galactokinase) and *Saccharomyces cerevisiae* GPD (glyceraldehyde-3-phosphate dehydrogenase) promoters.

A protein or fragment thereof encoding nucleic acid molecule of the invention may also be operably linked to a terminator sequence at its 3' terminus. The terminator sequence may be native to the nucleic acid sequence encoding the protein or fragment thereof or may be obtained from foreign sources. Any terminator which is functional in the fungal host cell of choice may be used in the invention, but particularly preferred terminators are obtained from the genes encoding *Aspergillus oryzae* TAKA amylase, *Aspergillus niger* glucoamylase, *Aspergillus nidulans* anthranilate synthase, *Aspergillus niger* alpha-glucosidase, *Saccharomyces cerevisiae* cytochrome-c oxidase (CYC1) and *Saccharomyces cerevisiae* *enlase*.

A protein or fragment thereof encoding nucleic acid molecule of the invention may also be operably linked to a suitable leader sequence. A leader sequence is a nontranslated region of a mRNA which is important for translation by the fungal host. The leader sequence is operably linked to the 5' terminus of the nucleic acid sequence encoding the protein or fragment thereof. The leader sequence may be native to the nucleic acid sequence encoding the protein or fragment thereof or may be obtained from foreign sources. Any leader sequence which is functional in the fungal host cell of choice may be used in the invention, but particularly preferred

leaders are obtained from the genes encoding *Aspergillus oryzae* TAKA amylase and *Aspergillus oryzae* triose phosphate isomerase.

A polyadenylation sequence may also be operably linked to the 3' terminus of the nucleic acid sequence of the invention. The polyadenylation sequence is a sequence which when transcribed is recognized by the fungal host to add polyadenosine residues to transcribed mRNA. The polyadenylation sequence may be native to the nucleic acid sequence encoding the protein or fragment thereof or may be obtained from foreign sources. Any polyadenylation sequence which is functional in the fungal host of choice may be used in the invention, but particularly preferred polyadenylation sequences are obtained from the genes encoding *Aspergillus oryzae* TAKA amylase, *Aspergillus niger* glucoamylase, *Aspergillus nidulans* anthranilate synthase, *Aspergillus niger* alpha-glucosidase and *Saccharomyces cerevisiae* cytochrome-c oxidase (CYC1).

To avoid the necessity of disrupting the cell to obtain the protein or fragment thereof and to minimize the amount of possible degradation of the expressed protein or fragment thereof within the cell, it is preferred that expression of the protein or fragment thereof gives rise to a product secreted outside the cell. To this end, a protein or fragment thereof of the invention may be linked to a signal peptide linked to the amino terminus of the protein or fragment thereof. A signal peptide is an amino acid sequence which permits the secretion of the protein or fragment thereof from the fungal host into the culture medium. The signal peptide may be native to the protein or fragment thereof of the invention or may be obtained from foreign sources. The 5' end of the coding sequence of the nucleic acid sequence of the invention may inherently contain a signal peptide coding region naturally linked in translation reading frame with the segment of the coding region which encodes the secreted protein or fragment thereof. Alternatively, the 5' end of the coding sequence may contain a signal peptide coding region which is foreign to that portion of the coding sequence which encodes the secreted protein or fragment thereof. The foreign signal peptide may be required where the coding sequence does not normally contain a signal peptide coding region. Alternatively, the foreign signal peptide may simply replace the natural signal peptide to obtain enhanced secretion of the desired protein or fragment thereof. The foreign signal peptide coding region may be obtained from a glucoamylase or an amylase gene from an *Aspergillus* species, a lipase or proteinase gene from *Rhizomucor miehei*, the gene for the alpha-factor from *Saccharomyces cerevisiae*, or the calf preprochymosin gene. An effective signal peptide for fungal host cells is the *Aspergillus oryzae* TAKA amylase signal, *Aspergillus niger* neutral amylase signal, the *Rhizomucor miehei* aspartic proteinase signal, the *Humicola lanuginosus* cellulase signal, or the *Rhizomucor miehei* lipase signal. However, any signal peptide capable of permitting secretion of the protein or fragment thereof in a fungal host of choice may be used in the invention.

A protein or fragment thereof encoding nucleic acid molecule of the invention may also be linked to a propeptide coding region. A propeptide is an amino acid sequence found at the amino terminus of a proprotein or proenzyme. Cleavage of the propeptide from the proprotein yields a mature biochemically active protein. The resulting polypeptide is known as a propeptide or proenzyme (or a zymogen in some cases). Propolypeptides are generally inactive and can be converted to mature active polypeptides by catalytic or autocatalytic cleavage of the propeptide from the propeptide or proenzyme. The propeptide coding region

may be native to the protein or fragment thereof or may be obtained from foreign sources. The foreign propeptide coding region may be obtained from the *Saccharomyces cerevisiae* alpha-factor gene or *Myceliophthora thermophila* laccase gene (WO 95/33836, the entirety of which is herein incorporated by reference).

The procedures used to ligate the elements described above to construct the recombinant expression vector of the invention are well known to one skilled in the art (see, for example, Sambrook et al., *Molecular Cloning, A Laboratory Manual*, 2nd ed., Cold Spring Harbor, N.Y., (1989)).

The invention also relates to recombinant fungal host cells produced by the methods of the invention which are advantageously used with the recombinant vector of the invention. The cell is preferably transformed with a vector comprising a nucleic acid sequence of the invention followed by integration of the vector into the host chromosome. The choice of fungal host cells will to a large extent depend upon the gene encoding the protein or fragment thereof and its source. The fungal host cell may, for example, be a yeast cell or a filamentous fungal cell.

"Yeast" as used herein includes Ascosporogenous yeast (Endomycetes). Basidiosporogenous yeast and yeast belonging to the *Fungi Imperfecti* (Blastomyces). The Ascosporogenous yeasts are divided into the families Spermophthoraceae and Saccharomycetaceae. The latter is comprised of four subfamilies. Schizosaccharomycetaceae (for example, genus *Schizosaccharomyces*), Nadsonioideae, Lipomycoideae and Saccharomycetaceae (for example, genera *Pichia*, *Kluyveromyces* and *Saccharomyces*). The Basidiosporogenous yeasts include the genera *Leucosporidium*, *Rhodospodium*, *Sporidiobolus*, *Filobasidium* and *Filobasidiella*. Yeast belonging to the *Fungi Imperfecti* are divided into two families, Sporobolomycetaceae (for example, genera *Sorobolomyces* and *Bullera*) and Cryptococcaceae (for example, genus *Candida*). Since the classification of yeast may change in the future, for the purposes of this invention, yeast shall be defined as described in *Biology and Activities of Yeast* (Skinner et al., *Soc. App. Bacteriol. Symposium Series* No. 9, (1980), the entirety of which is herein incorporated by reference). The biology of yeast and manipulation of yeast genetics are well known in the art (see, for example, *Biochemistry and Genetics of Yeast*, Bacil et al. (ed.), 2nd edition, 1987; *The Yeasts*, Rose and Harrison (eds.), 2nd ed., (1987); and *The Molecular Biology of the Yeast Saccharomyces*, Strathern et al., (1981), all of which are herein incorporated by reference in their entirety).

"Fungi" as used herein includes the phyla Ascomycota, Basidiomycota, Chytridiomycota and Zygomycota (as defined by Hawksworth et al., In: Ainsworth and Bisby's *Dictionary of The Fungi*, 8th edition, 1995, CAB International, University Press, Cambridge, UK; the entirety of which is herein incorporated by reference) as well as the Oomycota (as cited in Hawksworth et al., In: Ainsworth and Bisby's *Dictionary of The Fungi*, 8th edition, 1995, CAB International, University Press, Cambridge, UK) and all mitospic fungi (Hawksworth et al., In: Ainsworth and Bisby's *Dictionary of The Fungi*, 8th edition, 1995, CAB International, University Press, Cambridge, UK). Representative groups of Ascomycota include, for example, *Neurospora*, *Eupenicillium* (=Penicillium), *Emericella* (=Aspergillus), *Eurotium* (=Aspergillus) and the true yeasts listed above. Examples of Basidiomycota include mushrooms, rusts and smuts. Representative groups of Chytridiomycota include, for example, *Allomyces*, *Blastocladiella*, *Coelomomyces* and aquatic fungi. Representative groups of Oomycota include, for example, Sapro-

legniomycetous aquatic fungi (water molds) such as Achlya. Examples of mitosporic fungi include Aspergillus, Penicillium, Candida and Alternaria. Representative groups of Zygomycota include, for example, Rhizopus and Mucor.

"Filamentous fungi" include all filamentous forms of the subdivision Eumycota and Oomycota (as defined by Hawksworth et al., In: Ainsworth and Bisby's *Dictionary of The Fungi*, 8th edition, 1995, CAB International, University Press, Cambridge, UK). The filamentous fungi are characterized by a vegetative mycelium composed of chitin, cellulose, glucan, chitosan, mannan and other complex polysaccharides. Vegetative growth is by hyphal elongation and carbon catabolism is obligately aerobic. In contrast, vegetative growth by yeasts such as *Saccharomyces cerevisiae* is by budding of a unicellular thallus and carbon catabolism may be fermentative.

In one embodiment, the fungal host cell is a yeast cell. In a preferred embodiment, the yeast host cell is a cell of the species of *Candida*, *Kluyveromyces*, *Saccharomyces*, *Schizosaccharomyces*, *Pichia* and *Yarrowia*. In a preferred embodiment, the yeast host cell is a *Saccharomyces cerevisiae* cell, a *Saccharomyces carlsbergensis*, *Saccharomyces diastaticus* cell, a *Saccharomyces douglasi* cell, a *Saccharomyces kluyveri* cell, a *Saccharomyces norbensis* cell, or a *Saccharomyces oviformis* cell. In another preferred embodiment, the yeast host cell is a *Kluyveromyces lactis* cell. In another preferred embodiment, the yeast host cell is a *Yarrowia lipolytica* cell.

In another embodiment, the fungal host cell is a filamentous fungal cell. In a preferred embodiment, the filamentous fungal host cell is a cell of the species of, but not limited to, *Acremonium*, *Aspergillus*, *Fusarium*, *Humicola*, *Myceliophthora*, *Neurospora*, *Penicillium*, *Thielavia*, *Toly-polcladium* and *Trichoderma*.

The recombinant fungal host cells of the invention may further comprise one or more sequences which encode one or more factors that are advantageous in the expression of the protein or fragment thereof, for example, an activator (e.g., a trans-acting factor), a chaperone and a processing protease. The nucleic acids encoding one or more of these factors are preferably not operably linked to the nucleic acid encoding the protein or fragment thereof. An activator is a protein which activates transcription of a nucleic acid sequence encoding a polypeptide (Kudla et al., *EMBO* 9:1355-1364(1990); Jarai and Buxton, *Current Genetics* 26:2238-244(1994); Verdier, *Yeast* 6:271-297(1990), all of which are herein incorporated by reference in their entirety). The nucleic acid sequence encoding an activator may be obtained from the genes encoding *Saccharomyces cerevisiae* heme activator protein 1 (hap1), *Saccharomyces cerevisiae* galactose metabolizing protein 4 (gal4) and *Aspergillus nidulans* ammonia regulation protein (arcA). For further examples, see Verdier, *Yeast* 6:271-297 (1990); MacKenzie et al., *Journal of Gen. Microbiol.* 139:2295-2307 (1993), both of which are herein incorporated by reference in their entirety). A chaperone is a protein which assists another protein in folding properly (Hartl et al., *TIBS* 19:20-25 (1994); Bergeron et al., *TIBS* 19:124-128 (1994); Demolder et al., *J. Biotechnology* 32:179-189 (1994); Craig, *Science* 260:1902-1903(1993); Gething and Sambrook, *Nature* 355:33-45 (1992); Puig and Gilbert, *J Biol. Chem.* 269:7764-7771 (1994); Wang and Tsou, *FASEB Journal* 7:1515-11157 (1993); Robinson et al., *Bio/Technology* 1:381-384 (1994), all of which are herein incorporated by reference in their entirety). The nucleic acid sequence encoding a chaperone may be obtained from the genes encoding *Aspergillus oryzae* protein disulphide isomerase,

Saccharomyces cerevisiae calnexin, *Saccharomyces cerevisiae* BiP/GRP78 and *Saccharomyces cerevisiae* Hsp70. For further examples, see Gething and Sambrook, *Nature* 355:33-45 (1992); Hartl et al., *TIBS* 19:20-25 (1994). A processing protease is a protease that cleaves a propeptide to generate a mature biochemically active polypeptide (Enderlin and Ogrydziak, *Yeast* 10:67-79 (1994); Fuller et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 86:1434-1438 (1989); Julius et al., *Cell* 37:1075-1089 (1984); Julius et al., *Cell* 32:839-852 (1983), all of which are incorporated by reference in their entirety). The nucleic acid sequence encoding a processing protease may be obtained from the genes encoding *Aspergillus niger* Kex2, *Saccharomyces cerevisiae* dipeptidylaminopeptidase, *Saccharomyces cerevisiae* Kex2 and *Yarrowia lipolytica* dibasic processing endoprotease (xpr6). Any factor that is functional in the fungal host cell of choice may be used in the invention.

Fungal cells may be transformed by a process involving protoplast formation, transformation of the protoplasts and regeneration of the cell wall in a manner known per se. Suitable procedures for transformation of *Aspergillus* host cells are described in EP 238 023 and Yelton et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 81:1470-1474 (1984), both of which are herein incorporated by reference in their entirety. A suitable method of transforming *Fusarium* species is described by Malardier et al., *Gene* 78:147-156 (1989), the entirety of which is herein incorporated by reference. Yeast may be transformed using the procedures described by Becker and Guarente, In: Abelson and Simon, (eds.), *Guide to Yeast Genetics and Molecular Biology, Methods Enzymol.*, Volume 194, pp. 182-187, Academic Press, Inc., New York; Ito et al., *J. Bacteriology* 153:163 (1983); Hinnen et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 75:1920 (1978), all of which are herein incorporated by reference in their entirety.

The invention also relates to methods of producing the protein or fragment thereof comprising culturing the recombinant fungal host cells under conditions conducive for expression of the protein or fragment thereof. The fungal cells of the invention are cultivated in a nutrient medium suitable for production of the protein or fragment thereof using methods known in the art. For example, the cell may be cultivated by shake flask cultivation, small-scale or large-scale fermentation (including continuous, batch, fed-batch, or solid state fermentations) in laboratory or industrial fermentors performed in a suitable medium and under conditions allowing the protein or fragment thereof to be expressed and/or isolated. The cultivation takes place in a suitable nutrient medium comprising carbon and nitrogen sources and inorganic salts, using procedures known in the art (see, e.g., Bennett and LaSure (eds.), *More Gene Manipulations in Fungi*, Academic Press, CA. (1991), the entirety of which is herein incorporated by reference). Suitable media are available from commercial suppliers or may be prepared according to published compositions (e.g., in catalogues of the American Type Culture Collection, Manassas, Va.). If the protein or fragment thereof is secreted into the nutrient medium, a protein or fragment thereof can be recovered directly from the medium. If the protein or fragment thereof is not secreted, it is recovered from cell lysates. The expressed protein or fragment thereof may be detected using methods known in the art that are specific for the particular protein or fragment. These detection methods may include the use of specific antibodies, formation of an enzyme product, or disappearance of an enzyme substrate. For example, if the protein or fragment thereof has enzymatic activity, an enzyme assay may be used. Alternatively, if polyclonal or monoclonal antibodies specific to the protein

or fragment thereof are available, immunoassays may be employed using the antibodies to the protein or fragment thereof. The techniques of enzyme assay and immunoassay are well known to those skilled in the art.

The resulting protein or fragment thereof may be recovered by methods known in the arts. For example, the protein or fragment thereof may be recovered from the nutrient medium by conventional procedures including, but not limited to, centrifugation, filtration, extraction, spray-drying, evaporation, or precipitation. The recovered protein or fragment thereof may then be further purified by a variety of chromatographic procedures, e.g., ion exchange chromatography, gel filtration chromatography, affinity chromatography, or the like.

(g) Mammalian Constructs and Transformed Mammalian Cells

The invention also relates to methods for obtaining a recombinant mammalian host cell, comprising introducing into a mammalian host cell exogenous genetic material. The invention also relates to a mammalian cell comprising a mammalian recombinant vector. The invention also relates to methods for obtaining a recombinant mammalian host cell, comprising introducing into a mammalian cell exogenous genetic material. In a preferred embodiment the exogenous genetic material includes a nucleic acid molecule of the present invention, preferably a nucleic acid molecule having a sequence selected from the group consisting of SEQ ID NO: 1 through SEQ ID NO: 621 or complements thereof or fragments of either. Another preferred class of exogenous genetic material are nucleic acid molecules that encode a protein having an amino acid selected from the group consisting of SEQ ID NO: 622 through SEQ ID NO: 626 or fragments thereof.

Mammalian cell lines available as hosts for expression are known in the art and include many immortalized cell lines available from the American Type Culture Collection (ATCC, Manassas, Va.), such as HeLa cells, Chinese hamster ovary (CHO) cells, baby hamster kidney (BHK) cells and a number of other cell lines.

Suitable promoters for mammalian cells are also known in the art and include viral promoters, such as those from Simian Virus 40 (SV40) (Fiers et al., *Nature* 273: 113 (1978)), Rous sarcoma virus (RSV), adenovirus (ADV), cytomegalovirus (CMYV), and bovine papilloma virus (BPV), as well as mammalian cell-derived promoters. An exemplary, non-limiting, list includes: a hematopoietic stem cell-specific promoter, such as the CD34 promoter (Burn et al., U.S. Pat. No. 5,556,954); the glucose-6-phospholase promoter (Yoshiuchi et al., *J. Clin. Endocrin. Metab.* 83:1016-1019 (1998)); interleukin-1 alpha promoter (Mori and Prager, *Leuk. Lymphoma* 26:421-433 (1997)); CMV promoter (Tong et al., *Anticancer Res.* 18:719-725 (1998), Norman et al., *Vaccine* 15:801-803 (1997)); RSV promoter (Elshami et al., *Cancer Gene Ther.* 4:213-221 (1997); Baldwin et al., *Gene Ther.* 4:1142-1149 (1997)); SV40 promoter (Harms and Splitter, *Hun. Gene Ther.* 6:1291-1297 (1995)); CD11c integrin gene promoter (Corbi and Lopez-Rodriguez, *Leuk. Lymphoma* 25:415-425 (1997)), GM-CSF promoter (Shannon et al., *Crit. Rev. Immunol.* 17:301-323 (1997)); interleukin-5R alpha promoter (Sun et al., *Curr. Top. Microbiol. Immunol.* 211:173-187 (1996)); interleukin-2 promoter (Serfing et al., *Biochim. Biophys. Acta* 1263:181-200 (1995); O'Neill et al., *Transplant Proc.* 23:2862-2866 (1991)); c-fos promoter (Janknecht, *Immunobiology* 193:137-142 (1995), Janknecht et al., *Carcinogenesis* 16:443-450 (1995), Takai et al.,

Princess Takamatsu Symp. 22:197-204 (1991)); h-ras promoter (Rachal et al., *EXS* 64:330-342 (1993)); and DMD gene promoter (Ray et al., *Adv. Exp. Med. Biol.* 280:107-111 (1990). All of the above documents are incorporated by reference in their entirety and can be relied on to make or use aspects of this invention, especially in designing and constructing appropriate vector and host expression systems.

Vectors used in mammalian cell expression systems may also include additional functional sequences. For example, terminator sequences, poly-A addition sequences, and internal ribosome entry site (IRES) sequences. Enhancer sequences, which increase expression, may also be included and sequences that promote amplification of the gene may also be desirable (for example, methotrexate resistance genes). One of skill in the art is familiar with numerous examples of these additional functional sequences, as well as other functional sequences, that may optionally be included in an expression vector.

Vectors suitable for replication in mammalian cells may include viral replicons, or sequences which insure integration of the appropriate sequences encoding HCV epitopes into the host genome. For example, another vector used to express foreign DNA is vaccinia virus. In this case, for example, a nucleic acid molecule encoding a protein or fragment thereof is inserted into the vaccinia genome. Techniques for the insertion of foreign DNA into the vaccinia virus genome are known in the art and may utilize, for example, homologous recombination. Such heterologous DNA is generally inserted into a gene which is non-essential to the virus, for example, the thymidine kinase gene (tk), which also provides a selectable marker. Plasmid vectors that greatly facilitate the construction of recombinant viruses have been described (see, for example, Mackett et al., *J Virol.* 49:857 (1984); Chakrabarti et al., *Mol. Cell. Biol.* 5:3403 (1985); Moss, In: *Gene Transfer Vectors For Mammalian Cells* (Miller and Calos, eds., Cold Spring Harbor Laboratory, N.Y., p. 10, (1987); all of which are herein incorporated by reference in their entirety). Expression of the HCV polypeptide then occurs in cells or animals which are infected with the live recombinant vaccinia virus.

The sequence to be integrated into the mammalian sequence may be introduced into the primary host by any convenient means, which includes calcium precipitated DNA, spheroplast fusion, transformation, electroporation, biolistics, lipofection, microinjection, or other convenient means. Where an amplifiable gene is being employed, the amplifiable gene may serve as the selection marker for selecting hosts into which the amplifiable gene has been introduced. Alternatively, one may include with the amplifiable gene another marker, such as a drug resistance marker, e.g., neomycin resistance (G418 in mammalian cells), hygromycin in resistance etc., or an auxotrophy marker (HIS3, TRP1, LEU2, URA3, ADE2, LYS2, etc.) for use in yeast cells.

Depending upon the nature of the modification and associated targeting construct, various techniques may be employed for identifying targeted integration. Conveniently, the DNA may be digested with one or more restriction enzymes and the fragments probed with an appropriate DNA fragment which will identify the properly sized restriction fragment associated with integration.

One may use different promoter sequences, enhancer sequences, or other sequence which will allow for enhanced levels of expression in the expression host. Thus, one may combine an enhancer from one source, a promoter region from another source, a 5'-noncoding region upstream from

the initiation methionine from the same or different source as the other sequences and the like. One may provide for an intron in the non-coding region with appropriate splice sites or for an alternative 3'-untranslated sequence or polyadenylation site. Depending upon the particular purpose of the modification, any of these sequences may be introduced, as desired.

Where selection is intended, the sequence to be integrated will have with it a marker gene, which allows for selection. The marker gene may conveniently be downstream from the target gene and may include resistance to a cytotoxic agent, e.g., antibiotics, heavy metals, or the like, resistance or susceptibility to HAT, gancyclovir, etc., complementation to an auxotrophic host, particularly by using an auxotrophic yeast as the host for the subject manipulations, or the like. The marker gene may also be on a separate DNA molecule, particularly with primary mammalian cells. Alternatively, one may screen the various transformants, due to the high efficiency of recombination in yeast, by using hybridization analysis, PCR, sequencing, or the like.

For homologous recombination, constructs can be prepared where the amplifiable gene will be flanked, normally on both sides with DNA homologous with the DNA of the target region. Depending upon the nature of the integrating DNA and the purpose of the integration, the homologous DNA will generally be within 100 kb, usually 50 kb, preferably about 25 kb, of the transcribed region of the target gene, more preferably within 2 kb of the target gene. Where modeling of the gene is intended, homology will usually be present proximal to the site of the mutation. The homologous DNA may include the 5'-upstream region outside of the transcriptional regulatory region or comprising any enhancer sequences, transcriptional initiation sequences, adjacent sequences, or the like. The homologous region may include a portion of the coding region, where the coding region may be comprised only of an open reading frame or combination of exons and introns. The homologous region may comprise all or a portion of an intron, where all or a portion of one or more exons may also be present. Alternatively, the homologous region may comprise the 3'-region, so as to comprise all or a portion of the transcriptional termination region, or the region 3' of this region. The homologous regions may extend over all or a portion of the target gene or be outside the target gene comprising all or a portion of the transcriptional regulatory regions and/or the structural gene.

The integrating constructs may be prepared in accordance with conventional ways, where sequences may be synthesized, isolated from natural sources, manipulated, cloned, ligated, subjected to in vitro mutagenesis, primer repair, or the like. At various stages, the joined sequences may be cloned and analyzed by restriction analysis, sequencing, or the like. Usually during the preparation of a construct where various fragments are joined, the fragments, intermediate constructs and constructs will be carried on a cloning vector comprising a replication system functional in a prokaryotic host, e.g., *E. coli* and a marker for selection, e.g., biocide resistance, complementation to an auxotrophic host, etc. Other functional sequences may also be present, such as polylinkers, for ease of introduction and excision of the construct or portions thereof, or the like. A large number of cloning vectors are available such as pBR322 the pUC series, etc. These constructs may then be used for integration into the primary mammalian host.

In the case of the primary mammalian host, a replicating vector may be used. Usually, such vector will have a viral replication system, such as SV40, bovine papilloma virus,

adenovirus, or the like. The linear DNA sequence vector may also have a selectable marker for identifying transfected cells. Selectable markers include the neo gene, allowing for selection with G418, the herpes tk gene for selection with HAT medium, the gpt gene with mycophenolic acid, complementation of an auxotrophic host, etc.

The vector may or may not be capable of stable maintenance in the host. Where the vector is capable of stable maintenance, the cells will be screened for homologous integration of the vector into the genome of the host, where various techniques for curing the cells may be employed. Where the vector is not capable of stable maintenance, for example, where a temperature sensitive replication system is employed, one may change the temperature from the permissive temperature to the non-permissive temperature, so that the cells may be cured of the vector. In this case, only those cells having integration of the construct comprising the amplifiable gene and, when present, the selectable marker, will be able to survive selection.

Where a selectable marker is present, one may select for the presence of the targeting construct by means of the selectable marker. Where the selectable marker is not present, one may select for the presence of the construct by the amplifiable gene. For the neo gene or the herpes tk gene, one could employ a medium for growth of the transformants of about 0.1–1 mg/ml of G418 or may use HAT medium, respectively. Where DHFR is the amplifiable gene, the selective medium may include from about 0.01–0.5 μ M of methotrexate or be deficient in glycine-hypoxanthine-thymidine and have dialysed serum (GHT media).

The DNA can be introduced into the expression host by a variety of techniques that include calcium phosphate/DNA co-precipitates, microinjection of DNA into the nucleus, electroporation, yeast protoplast fusion with intact cells, transfection, polycations, e.g., polybrene, polyornithine, etc., or the like. The DNA may be single or double stranded DNA, linear or circular. The various techniques for transforming mammalian cells are well known (see Keown et al., *Methods Enzymol.* (1989); Keown et al., *Methods Enzymol.* 185:527–537 (1990); Mansour et al., *Nature* 336:348–352, (1988); all of which are herein incorporated by reference in their entirety).

(h) Insect Constructs and Transformed Insect Cells

The invention also relates to an insect recombinant vectors comprising exogenous genetic material. The invention also relates to an insect cell comprising an insect recombinant vector. The invention also relates to methods for obtaining a recombinant insect host cell, comprising introducing into an insect cell exogenous genetic material. In a preferred embodiment the exogenous genetic material includes a nucleic acid molecule of the present invention, preferably a nucleic acid molecule having a sequence selected from the group consisting of SEQ ID NO: 1 through SEQ ID NO: 621 or complements thereof or fragments of either. Another preferred class of exogenous genetic material are nucleic acid molecules that encode a protein having an amino acid selected from the group consisting of SEQ ID NO: 622 through SEQ ID NO: 626 or fragments thereof.

The insect recombinant vector may be any vector which can be conveniently subjected to recombinant DNA procedures and can bring about the expression of the nucleic acid sequence. The choice of a vector will typically depend on the compatibility of the vector with the insect host cell into which the vector is to be introduced. The vector may be a linear or a closed circular plasmid. The vector system may be a single vector or plasmid or two or more vectors or

plasmids which together contain the total DNA to be introduced into the genome of the insect host. In addition, the insect vector may be an expression vector. Nucleic acid molecules can be suitably inserted into a replication vector for expression in the insect cell under a suitable promoter for insect cells. Many vectors are available for this purpose and selection of the appropriate vector will depend mainly on the size of the nucleic acid molecule to be inserted into the vector and the particular host cell to be transformed with the vector. Each vector contains various components depending on its function (amplification of DNA or expression of DNA) and the particular host cell with which it is compatible. The vector components for insect cell transformation generally include, but are not limited to, one or more of the following: a signal sequence, origin of replication, one or more marker genes and an inducible promoter.

The insect vector may be an autonomously replicating vector, i.e., a vector which exists as an extrachromosomal entity, the replication of which is independent of chromosomal replication, e.g., a plasmid, an extrachromosomal element, a minichromosome, or an artificial chromosome. The vector may contain any means for assuring self-replication. Alternatively, the vector may be one which, when introduced into the insect cell, is integrated into the genome and replicated together with the chromosome(s) into which it has been integrated. For integration, the vector may rely on the nucleic acid sequence of the vector for stable integration of the vector into the genome by homologous or nonhomologous recombination. Alternatively, the vector may contain additional nucleic acid sequences for directing integration by homologous recombination into the genome of the insect host. The additional nucleic acid sequences enable the vector to be integrated into the host cell genome at a precise location(s) in the chromosome(s). To increase the likelihood of integration at a precise location, there should be preferably two nucleic acid sequences which individually contain a sufficient number of nucleic acids, preferably 400 bp to 1500 bp, more preferably 800 bp to 1000 bp, which are highly homologous with the corresponding target sequence to enhance the probability of homologous recombination. These nucleic acid sequences may be any sequence that is homologous with a target sequence in the genome of the insect host cell and, furthermore, may be non-encoding or encoding sequences.

Baculovirus expression vectors (BEVs) have become important tools for the expression of foreign genes, both for basic research and for the production of proteins with direct clinical applications in human and veterinary medicine (Doerfler, *Curr. Top. Microbiol. Immunol.* 131:51-68 (1968); Luckow and Summers, *Bio/Technology* 6:47-55 (1988a); Miller, *Annual Review of Microbiol.* 42: 177-199 (1988); Summers, *Curr. Comm. Molecular Biology*, Cold Spring Harbor Press, Cold Spring Harbor, N.Y. (1988); all of which are herein incorporated by reference in their entirety). BEVs are recombinant insect viruses in which the coding sequence for a chosen foreign gene has been inserted behind a baculovirus promoter in place of the viral gene, e.g., polyhedrin (Smith and Summers, U.S. Pat. No. 4,745,051, the entirety of which is incorporated herein by reference).

The use of baculovirus vectors relies upon the host cells being derived from Lepidopteran insects such as *Spodoptera frugiperda* or *Trichoplusia ni*. The preferred *Spodoptera frugiperda* cell line is the cell line Sf9. The *Spodoptera frugiperda* Sf9 cell line was obtained from American Type Culture Collection (Manassas, Va.) and is assigned accession number ATCC CRL 1711 (Summers and Smith, *A Manual of Methods for Baculovirus Vectors and Insect Cell*

Culture Procedures, Texas Ag. Exper. Station Bulletin No. 1555 (1988), the entirety of which is herein incorporated by reference). Other insect cell systems, such as the silkworm *B. mori* may also be used.

The proteins expressed by the BEVs are, therefore, synthesized, modified and transported in host cells derived from Lepidopteran insects. Most of the genes that have been inserted and produced in the baculovirus expression vector system have been derived from vertebrate species. Other baculovirus genes in addition to the polyhedrin promoter may be employed to advantage in a baculovirus expression system. These include immediate-early (alpha), delayed-early (beta), late (gamma), or very late (delta), according to the phase of the viral infection during which they are expressed. The expression of these genes occurs sequentially, probably as the result of a "cascade" mechanism of transcriptional regulation. (Guarino and Summers, *J. Virol.* 57:563-571 (1986); Guarino and Summers, *J. Virol.* 61:2091-2099 (1987); Guarino and Summers, *Virol.* 162:444-451 (1988); all of which are herein incorporated by reference in their entirety).

Insect recombinant vectors are useful as intermediates for the infection or transformation of insect cell systems. For example, an insect recombinant vector containing a nucleic acid molecule encoding a baculovirus transcriptional promoter followed downstream by an insect signal DNA sequence is capable of directing the secretion of the desired biologically active protein from the insect cell. The vector may utilize a baculovirus transcriptional promoter region derived from any of the over 500 baculoviruses generally infecting insects, such as for example the Orders Lepidoptera, Diptera, Orthoptera, Coleoptera and Hymenoptera, including for example but not limited to the viral DNAs of *Autographa californica* MNPV, *Bombyx mori* NPV, *Tricoplusia ni* MNPV, *Rachiplusia ou* MNPV or *Galleria mellonella* MNPV, wherein said baculovirus transcriptional promoter is a baculovirus immediate-early gene IE1 or IEN promoter; an immediate-early gene in combination with a baculovirus delayed-early gene promoter region selected from the group consisting of 39K and a HindIII-k fragment delayed-early gene; or a baculovirus late gene promoter. The immediate-early or delayed-early promoters can be enhanced with transcriptional enhancer elements. The insect signal DNA sequence may code for a signal peptide of a Lepidopteran adipokinetic hormone precursor or a signal peptide of the *Manduca sexta* adipokinetic hormone precursor (Summers, U.S. Pat. No. 5,155,037; the entirety of which is herein incorporated by reference). Other insect signal DNA sequences include a signal peptide of the *Orthoptera Schistocerca gregaria* locust adipokinetic hormone precursor and the *Drosophila melanogaster* cuticle genes CP1, CP2, CP3 or CP4 or for an insect signal peptide having substantially a similar chemical composition and function (Summers, U.S. Pat. No. 5,155,037).

Insect cells are distinctly different from animal cells. Insects have a unique life cycle and have distinct cellular properties such as the lack of intracellular plasminogen activators in which are present in vertebrate cells. Another difference is the high expression levels of protein products ranging from 1 to greater than 500 mg/liter and the ease at which cDNA can be cloned into cells (Frasier, *In Vitro Cell. Dev. Biol.* 25:225 (1989); Summers and Smith, In: *A Manual of Methods for Baculovirus Vectors and Insect Cell Culture Procedures*, Texas Ag. Exper. Station Bulletin No. 1555 (1988), both of which are incorporated by reference in their entirety).

Recombinant protein expression in insect cells is achieved by viral infection or stable transformation. For viral

infection, the desired gene is cloned into baculovirus at the site of the wild-type polyhedron gene (Webb and Summers, *Technique* 2:173 (1990); Bishop and Posse, *Adv. Gene Technol.* 1:55 (1990); both of which are incorporated by reference in their entirety). The polyhedron gene is a component of a protein coat in occlusions which encapsulate virus particles. Deletion or insertion in the polyhedron gene results the failure to form occlusion bodies. Occlusion negative viruses are morphologically different from occlusion positive viruses and enable one skilled in the art to identify and purify recombinant viruses.

The vectors of invention preferably contain one or more selectable markers, which permit easy selection of transformed cells. A selectable marker is a gene the product of which provides, for example biocide or viral resistance, resistance to heavy metals, prototrophy to auxotrophs and the like. Selection may be accomplished by co-transformation, e.g., as described in WO 91/17243, a nucleic acid sequence of the invention may be operably linked to a suitable promoter sequence. The promoter sequence is a nucleic acid sequence, which is recognized by the insect host cell for expression of the nucleic acid sequence. The promoter sequence contains transcription and translation control sequences, which mediate the expression of the protein or fragment thereof. The promoter may be any nucleic acid sequence, which shows transcriptional activity in the insect host cell of choice and may be obtained from genes encoding polypeptides either homologous or heterologous to the host cell.

For example, a nucleic acid molecule encoding a protein or fragment thereof may also be operably linked to a suitable leader sequence. A leader sequence is a nontranslated region of a mRNA, which is important for translation by the fungal host. The leader sequence is operably linked to the 5' terminus of the nucleic acid sequence encoding the protein or fragment thereof. The leader sequence may be native to the nucleic acid sequence encoding the protein or fragment thereof or may be obtained from foreign sources. Any leader sequence, which is functional in the insect host cell of choice may be used in the invention.

A polyadenylation sequence may also be operably linked to the 3' terminus of the nucleic acid sequence of the invention. The polyadenylation sequence is a sequence which when transcribed is recognized by the insect host to add polyadenosine residues to transcribed mRNA. The polyadenylation sequence may be native to the nucleic acid sequence encoding the protein or fragment thereof or may be obtained from foreign sources. Any polyadenylation sequence, which is functional in the fungal host of choice, may be used in the invention.

To avoid the necessity of disrupting the cell to obtain the protein or fragment thereof and to minimize the amount of possible degradation of the expressed polypeptide within the cell, it is preferred that expression of the poly peptide gene gives rise to a product secreted outside the cell. To this end, the protein or fragment thereof of the invention may be linked to a signal peptide linked to the amino terminus of the protein or fragment thereof. A signal peptide is an amino acid sequence which permits the secretion of the protein or fragment thereof from the insect host into the culture medium. The signal peptide may be native to the protein or fragment thereof of the invention or may be obtained from foreign sources. The 5' end of the coding sequence of the nucleic acid sequence of the invention may inherently contain a signal peptide coding region naturally linked in translation reading frame with the segment of the coding region which encodes the secreted protein or fragment thereof.

At present, a mode of achieving secretion of a foreign gene product in insect cells is by way of the foreign gene's native signal peptide. Because the foreign genes are usually from non-insect organisms, their signal sequences may be poorly recognized by insect cells and, hence, levels of expression may be suboptimal. However, the efficiency of expression of foreign gene products seems to depend primarily on the characteristics of the foreign protein. On average, nuclear localized or non-structural proteins are most highly expressed, secreted proteins are intermediate and integral membrane proteins are the least expressed. One factor generally affecting the efficiency of the production of foreign gene products in a heterologous host system is the presence of native signal sequences (also termed presequences, targeting signals, or leader sequences) associated with the foreign gene. The signal sequence is generally coded by a DNA sequence immediately following (5' to 3') the translation start site of the desired foreign gene.

The expression dependence on the type of signal sequence associated with a gene product can be represented by the following example. If a foreign gene is inserted at a site downstream from the translational start site of the baculovirus polyhedrin gene so as to produce a fusion protein (containing the N-terminus of the polyhedrin structural gene), the fused gene is highly expressed. But less expression is achieved when a foreign gene is inserted in a baculovirus expression vector immediately following the transcriptional start site and totally replacing the polyhedrin structural gene.

Insertions into the region -50 to -1 significantly alter (reduce) steady state transcription which, in turn, reduces translation of the foreign gene product. Use of the pVL941 vector optimizes transcription of foreign genes to the level of the polyhedrin gene transcription. Even though the transcription of a foreign gene may be optimal, optimal translation may vary because of several factors involving processing: signal peptide recognition, mRNA and ribosome binding, glycosylation, disulfide bond formation, sugar processing, oligomerization, for example.

The properties of the insect signal peptide are expected to be more optimal for the efficiency of the translation process in insect cells than those from vertebrate proteins. This phenomenon can generally be explained by the fact that proteins secreted from cells are synthesized as precursor molecules containing hydrophobic N-terminal signal peptides. The signal peptides direct transport of the select protein to its target membrane and are then cleaved by a peptidase on the membrane, such as the endoplasmic reticulum, when the protein passes through it.

Another exemplary insect signal sequence is the sequence encoding for *Drosophila* cuticle proteins such as CP1, CP2, CP3 or CP4 (Summers, U.S. Pat. No. 5,278,050; the entirety of which is herein incorporated by reference). Most of a 9 kb region of the *Drosophila* genome containing genes for the cuticle proteins has been sequenced. Four of the five cuticle genes contains a signal peptide coding sequence interrupted by a short intervening sequence (about 60 base pairs) at a conserved site. Conserved sequences occur in the 5' mRNA untranslated region, in the adjacent 35 base pairs of upstream flanking sequence and at -200 base pairs from the mRNA start position in each of the cuticle genes.

Standard methods of insect cell culture, cotransfection and preparation of plasmids are set forth in Summers and Smith (Summers and Smith, *A Manual of Methods for Baculovirus Vectors and Insect Cell Procedures*, Texas Agricultural Experiment Station Bulletin No. 1555. Texas

A&M University (1987)). Procedures for the cultivation of viruses and cells are described in Volkman and Summers, *J. Virol.* 19:820-832 (1975) and Volkman et al., *J. Virol.* 19:820-832 (1976); both of which are herein incorporated by reference in their entirety.

(i) Bacterial Constructs and Transformed Bacterial Cells

The invention also relates to a bacterial recombinant vector comprising exogenous genetic material. The invention also relates to a bacteria cell comprising a bacterial recombinant vector. The invention also relates to methods for obtaining a recombinant bacteria host cell, comprising introducing into a bacterial host cell exogenous genetic material. In a preferred embodiment the exogenous genetic material includes a nucleic acid molecule of the present invention, preferably a nucleic acid molecule having a sequence selected from the group consisting of SEQ ID NO. 1 through SEQ ID NO: 621 or complements thereof or fragments of either. Another preferred class of exogenous genetic material are nucleic acid molecules that encode a protein having an amino acid selected from the group consisting of SEQ ID NO: 622 through SEQ ID NO: 626 or fragments thereof.

The bacterial recombinant vector may be any vector that can be conveniently subjected to recombinant DNA procedures. The choice of a vector will typically depend on the compatibility of the vector with the bacterial host cell into which the vector is to be introduced. The vector may be a linear or a closed circular plasmid. The vector system may be a single vector or plasmid or two or more vectors or plasmids, which together contain the total DNA to be introduced into the genome of the bacterial host. In addition, the bacterial vector may be an expression vector. Nucleic acid molecules encoding protein homologues or fragments thereof can, for example, be suitably inserted into a replicable vector for expression in the bacterium under the control of a suitable promoter for bacteria. Many vectors are available for this purpose and selection of the appropriate vector will depend mainly on the size of the nucleic acid to be inserted into the vector and the particular host cell to be transformed with the vector. Each vector contains various components depending on its function (amplification of DNA or expression of DNA) and the particular host cell with which it is compatible. The vector components for bacterial transformation generally include, but are not limited to, one or more of the following: a signal sequence, an origin of replication, one or more marker genes and an inducible promoter.

In general, plasmid vectors containing replicon and control sequences that are derived from species compatible with the host cell are used in connection with bacterial hosts. The sector ordinarily carries a replication site, as well as marking sequences that are capable of providing phenotypic selection in transformed cells. For example, *E. coli* is typically transformed using pBR322, a plasmid derived from an *E. coli* species (see, e.g., Bolivar et al., *Gene* 2:95 (1977), the entirety of which is herein incorporated by reference). The plasmid pBR322 contains genes for ampicillin and tetracycline resistance and thus provides easy means for identifying transformed cells. The pBR322 plasmid, or other microbial plasmid or phage, also generally contains, or is modified to contain, promoters that can be used by the microbial organism for expression of the selectable marker genes.

Nucleic acid molecules encoding protein or fragments thereof may be expressed not only directly, but also as a fusion with another polypeptide, preferably a signal sequence or other polypeptide having a specific cleavage site

at the N-terminus of the mature polypeptide. In general, the signal sequence may be a component of the vector, or it may be a part of the polypeptide DNA that is inserted into the vector. The heterologous signal sequence selected should be one that is recognized and processed (i.e., cleaved by a signal peptidase) by the host cell. For bacterial host cells that do not recognize and process the native polypeptide signal sequence, the signal sequence is substituted by a bacterial signal sequence selected, for example, from the group consisting of the alkaline phosphatase, penicillinase, lpp, or heat-stable enterotoxin II leaders.

Both expression and cloning vectors contain a nucleic acid sequence that enables the vector to replicate in one or more selected host cells. Generally, in cloning vectors this sequence is one that enables the vector to replicate independently of the host chromosomal DNA and includes origins of replication or autonomously replicating sequences. Such sequences are well known for a variety of bacteria. The origin of replication from the plasmid pBR322 is suitable for most Gram-negative bacteria.

Expression and cloning vectors also generally contain a selection gene, also termed a selectable marker. This gene encodes a protein necessary for the survival or growth of transformed host cells grown in a selective culture medium. Host cells not transformed with the vector containing the selection gene will not survive in the culture medium. Typical selection genes encode proteins that (a) confer resistance to antibiotics or other toxins, e.g., ampicillin, neomycin, methotrexate, or tetracycline. (b) complement auxotrophic deficiencies, or (c) supply critical nutrients not available from complex media, e.g., the gene encoding D-alanine racemase for *Bacilli*. One example of a selection scheme utilizes a drug to arrest growth of a host cell. Those cells that are successfully transformed with a heterologous protein homologue or fragment thereof produce a protein conferring drug resistance and thus survive the selection regimen.

The expression vector for producing a protein or fragment thereof can also contain an inducible promoter that is recognized by the host bacterial organism and is operably linked to the nucleic acid encoding, for example, the nucleic acid molecule encoding the protein homologue or fragment thereof of interest. Inducible promoters suitable for use with bacterial hosts include the β -lactamase and lactose promoter systems (Chang et al., *Nature* 275:615 (1978); Goeddel et al., *Nature* 281:544 (1979); both of which are herein incorporated by reference in their entirety), the arabinose promoter system (Guzman et al., *J. Bacteriol.* 174:7716-7728 (1992); the entirety of which is herein incorporated by reference), alkaline phosphatase, a tryptophan (*trp*) promoter system (Goeddel, *Nucleic Acids Res.* 8:4057 (1980); EP 36,776; both of which are herein incorporated by reference in their entirety) and hybrid promoters such as the *tac* promoter (deBoer et al., *Proc. Natl. Acad. Sci. (USA)* 80:21-25 (1983); the entirety of which is herein incorporated by reference). However, other known bacterial inducible promoters are suitable (Siebenlist et al., *Cell* 20:269 (1980); the entirety of which is herein incorporated by reference).

Promoters for use in bacterial systems also generally contain a Shine-Dalgarno (S.D.) sequence operably linked to the DNA encoding the polypeptide of interest. The promoter can be removed from the bacterial source DNA by restriction enzyme digestion and inserted into the vector containing the desired DNA.

Construction of suitable sectors containing one or more of the above-listed components employs standard ligation tech-

niques. Isolated plasmids or DNA fragments are cleaved, tailored and re-ligated in the form desired to generate the plasmids required. Examples of available bacterial expression sectors include, but are not limited to: the multifunctional *E. coli* cloning and expression vectors such as Bluescript™ (Stratagene, La Jolla, Calif.), in which, for example, encoding an *A. nidulans* protein homologue or fragment thereof homologue, may be ligated into the vector in frame with sequences for the amino-terminal Met and the subsequent 7 residues of β -galactosidase so that a hybrid protein is produced; pIN vectors (Van Heeke and Schuster, *J. Biol. Chem.* 264:5503–5509 (1989), the entirety of which is herein incorporated by reference); and the like. pGEX vectors (Promega, Madison Wis. U.S.A.) may also be used to express foreign polypeptides as fusion proteins with glutathione S-transferase (GST). In general, such fusion proteins are soluble and can easily be purified from lysed cells by adsorption to glutathione-agarose beads followed by elution in the presence of free glutathione. Proteins made in such systems are designed to optionally include a heparin, thrombin, or factor XA protease cleavage sites so that the cloned polypeptide of interest can be released from the GST moiety at will. Proteins or polypeptides of the invention can be expressed as variants that facilitate purification. For example, a fusion protein to such proteins as maltose binding protein (MBP), glutathione-S-transferase (GST) or thioredoxin (TRX) are known in the art [New England BioLab, Beverly, Mass., Pharmacia, Piscataway, N.J., and Invitrogen, San Diego, Calif.]. The polypeptide or protein can also be a tagged variant to facilitate purification, such as with histidine or methionine rich regions (His-Tag; available from LifeTechnologies Inc. Gaithersburg, Md.) that bind to metal ion affinity chromatography columns, or with an epitope that binds to a specific antibody (Flag, available from Kodak, New Haven, Conn.). An exemplary, non-limiting list of commercially available vectors suitable for fusion protein expression includes: pBR322 (Promega); pGEX (Amersham); pT7 (USB); pET (Novagen); pIBI (IBI); pProEX-1 (Gibco/BRL); pBluescript II (Stratagene); pTZ18R and pTZ19R (USB); pSE420 (Invitrogen); pVL1392 (Invitrogen); pBlueBac (Invitrogen); pBacPAK (Clontech); pHIL (Invitrogen); pYES2 (Invitrogen); pCDNA (Invitrogen); and pREP (Invitrogen). A number of other purification methods or means are also known and can be used. Reverse-phase high performance liquid chromatography (RP-HPLC), optionally employing hydrophobic RP-HPLC media, e.g., silica gel, further purify the protein. Combinations of methods and means can also be employed to provide a substantially purified recombinant polypeptide or protein. Isolated plasmids or DNA fragments are cleaved, tailored, and re-ligated in the form desired to generate the plasmids required. Examples of available bacterial expression vectors include, but are not limited to, the multifunctional *E. coli* cloning and expression vectors such as Bluescript Registered™ (Stratagene, La Jolla, Calif.), in which, for example, encoding an gene homologue or fragment thereof homologue, may be ligated into the vector in frame with sequences for the amino-terminal Met and the subsequent 7 residues of beta-galactosidase so that a hybrid protein is produced; pIN vectors (Van Heeke and Schuster *J. Biol. Chem.* 264: 5503–5509 (1989). The entirety of which is herein incorporated by reference); and the like. pGEX vectors (Promega, Madison Wis.) may also be used to express foreign polypeptides as fusion proteins with glutathione S-transferase (GST). In general, such fusion proteins are soluble and can easily be purified from lysed cells by adsorption to glutathione-agarose beads followed by

elution in the presence of free glutathione. Proteins made in such systems are designed to include heparin, thrombin or factor XA protease cleavage sites so that the cloned polypeptide of interest can be released from the GST moiety at will.

Suitable host bacteria for a bacterial vector include archaeobacteria and eubacteria, especially eubacteria and most preferably Enterobacteriaceae. Examples of useful bacteria include *Escherichia*, *Enterobacter*, *Azotobacter*, *Erwinia*, *Bacillus*, *Pseudomonas*, *Klebsiella*, *Proteus*, *Salmonella*, *Serratia*, *Shigella*, *Rhizobia*, *Vitreoscilla* and *Paracoccus*. Suitable *E. coli* hosts include *E. coli* W3110 (American Type Culture Collection (ATCC) 27,325, Manassas, Va. U.S.A.), *E. coli* 294 (ATCC 31,446), *E. coli* B and *E. coli* X1776 (ATCC 31,537). These examples are illustrative rather than limiting. Mutant cells of any of the above-mentioned bacteria may also be employed. It is, of course, necessary to select the appropriate bacteria taking into consideration replicability of the replicon in the cells of a bacterium. For example, *E. coli*, *Serratia*, or *Salmonella* species can be suitably used as the host when well known plasmids such as pBR322, pBR325, pACYC177, or pKN410 are used to supply the replicon. *E. coli* strain W3110 is a preferred host or parent host because it is a common host strain for recombinant DNA product fermentations. Preferably, the host cell should secrete minimal amounts of proteolytic enzymes.

Host cells are transfected and preferably transformed with the above-described sectors and cultured in conventional nutrient media modified as appropriate for inducing promoters, selecting transformants, or amplifying the genes encoding the desired sequences.

Numerous methods of transfection are known to the ordinarily skilled artisan, for example, calcium phosphate and electroporation. Depending on the host cell used, transformation is done using standard techniques appropriate to such cells. The calcium treatment employing calcium chloride, as described in section 1.82 of Sambrook et al., *Molecular Cloning: A Laboratory Manual*, New York: Cold Spring Harbor Laboratory Press, (1989), is generally used for bacterial cells that contain substantial cell-wall barriers. Another method for transformation employs polyethylene glycol/DMSO, as described in Chung and Miller (Chung and Miller, *Nucleic Acids Res.* 16:3580 (1988); the entirety of which is herein incorporated by reference). Yet another method is the use of the technique termed electroporation.

Bacterial cells used to produce the polypeptide of interest for purposes of this invention are cultured in suitable media in which the promoters for the nucleic acid encoding the heterologous polypeptide can be artificially induced as described generally, e.g., in Sambrook et al., *Molecular Cloning: A Laboratory Manual*, New York; Cold Spring Harbor Laboratory Press, (1989). Examples of suitable media are Vixen in U.S. Pat. Nos. 5,304,472 and 5,342,763; both of which are incorporated by reference in their entirety.

In addition to the above discussed procedures, practitioners are familiar with the standard resource materials which describe specific conditions and procedures for the construction, manipulation and isolation of macromolecules (e.g., DNA molecules, plasmids, etc.), generation of recombinant organisms and the screening and isolating of clones, (see for example, Sambrook et al., *Molecular Cloning: A Laboratory Manual*, Cold Spring Harbor Press (1989); Mailga et al., *Methods in Plant Molecular Biology*, Cold Spring Harbor Press (1995), the entirety of which is herein incorporated by reference; Birren et al., *Genome Analysis: Analyzing DNA*, 1, Cold Spring Harbor, N.Y., the entirety of which is herein incorporated by reference).

(j) Algal Constructs and Algal Transformants

The present invention also relates to an algal recombinant vector comprising exogenous genetic material. The present invention also relates to an algal cell comprising an algal recombinant vector. The present invention also relates to methods for obtaining a recombinant algal host cell comprising introducing into an algal host cell exogenous genetic material.

Exogenous genetic material is any genetic material, whether naturally occurring or otherwise, from any source that is capable of being inserted into any organism. Exogenous genetic material may be transferred into an algal cell. In a preferred embodiment the exogenous genetic material includes a nucleic acid molecule having a sequence selected from the group consisting of SEQ ID NO: 1 through SEQ ID NO: 621 or complements thereof. Another preferred class of exogenous genetic material are nucleic acid molecules that encode a protein having an amino acid selected from the group consisting of SEQ ID NO: 622 through SEQ ID NO: 626 or fragments thereof.

The algal recombinant vector may be any vector which can be conveniently subjected to recombinant DNA procedures. The choice of a vector will typically depend on the compatibility of the vector with the algal host cell into which the vector is to be introduced. The vector may be a linear or a closed circular plasmid. The vector system may be a single vector or plasmid or two or more vectors or plasmids which together contain the total DNA to be introduced into the genome of the algal host.

The algal vector may be an autonomously replicating vector, i.e., a vector which exists as an extrachromosomal entity, the replication of which is independent of chromosomal replication. e.g., a plasmid, an extrachromosomal element, a minichromosome, or an artificial chromosome. The vector may contain any means for assuring self-replication. Alternatively, the vector may be one which, when introduced into the algal cell, is integrated into the genome and replicated together with the chromosome(s) into which it has been integrated. For integration, the vector may rely on the nucleic acid sequence of the vector for stable integration of the vector into the genome by homologous or nonhomologous recombination. Alternatively, the vector may contain additional nucleic acid sequences for directing integration by homologous recombination into the genome of the algal host. The additional nucleic acid sequences enable the vector to be integrated into the host cell genome at a precise location(s) in the chromosome(s). To increase the likelihood of integration at a precise location, there should be preferably two nucleic acid sequences which individually contain a sufficient number of nucleic acids, preferably 400 bp to 1500 bp, more preferably 800 bp to 1000 bp, which are highly homologous with the corresponding target sequence to enhance the probability of homologous recombination. These nucleic acid sequences may be any sequence that is homologous with a target sequence in the genome of the algal host cell, and, furthermore, may be non-encoding or encoding sequences.

The vectors of the present invention preferably contain one or more selectable markers which permit easy selection of transformed cells. A selectable marker is a gene, the product of which confers upon an algal cell resistance to a compound to which the algal would otherwise be sensitive. The compound can be selected from the group consisting of antibiotics, fungicides, herbicides, and heavy metals. The selectable marker may be selected from any known or subsequently identified selectable markers, including mark-

ers derived from algal, fungal, and bacterial sources. Preferred selectable markers can be selected from the group including, but not limited to, *amdS* (acetamidase), *argB* (ornithine carbamoyltransferase), *bar* (phosphinothricin acetyltransferase), *ble* (bleomycin binding protein), *cat* (chloramphenicol acetyltransferase), *hygB* (hygromycin B phosphotransferase), *nat* (nourseothricin acetyltransferase), *niaD* (nitrate reductase), *neo* (neomycin phosphotransferase), *pac* puromycin acetyltransferase), *pyrG* (orotidine-5'-phosphate decarboxylase), *sat* (streptothricin acetyltransferase), *sC* (sulfate adenylyltransferase), *trpC* (anthranilate synthase), and glyphosate resistant EPSPS genes. Furthermore, selection may be accomplished by co-transformation, e.g., as described in WO 91/172143, herein incorporated by reference in its entirety.

A nucleic acid sequence of the present invention may be operably linked to a suitable promoter sequence. The promoter sequence is a nucleic acid sequence which is recognized by the algal host cell for expression of the nucleic acid sequence. The promoter sequence contains transcription and translation control sequences which mediate the expression of the protein or fragment thereof.

A promoter may be any nucleic acid sequence which shows transcriptional activity in the algal host cell of choice and may be obtained from genes encoding polypeptides either homologous or heterologous to the host cell. Examples of suitable promoters for directing the transcription of a nucleic acid construct of the invention in an algal host are light harvesting protein promoters obtained from photosynthetic organisms, *Chorella* virus methyltransferase promoters, CaMV 35 S promoter, PL promoter from bacteriophage λ , nopaline synthase promoter from the Ti plasmid of *Agrobacterium tumefaciens*, and bacterial *trp* promoter.

A protein or fragment thereof encoding nucleic acid molecule of the present invention may also be operably linked to a terminator sequence at its 3' terminus. The terminator sequence may be native to the nucleic acid sequence encoding the protein or fragment thereof or may be obtained from foreign sources. Any terminator which is functional in the algal host cell of choice may be used in the present invention.

A protein or fragment thereof encoding nucleic acid molecule of the present invention may also be operably linked to a suitable leader sequence. A leader sequence is a nontranslated region of a mRNA which is important for translation by the algal host. The leader sequence is operably linked to the 5' terminus of the nucleic acid sequence encoding the protein or fragment thereof. The leader sequence may be native to the nucleic acid sequence encoding the protein or fragment thereof or may be obtained from foreign sources. Any leader sequence which is functional in the algal host cell of choice may be used in the present invention.

A polyadenylation sequence may also be operably linked to the 3' terminus of the nucleic acid sequence of the present invention. The polyadenylation sequence is a sequence which when transcribed is recognized by the algal host to add polyadenosine residues to transcribed mRNA.

The polyadenylation sequence may be native to the nucleic acid sequence encoding the protein or fragment thereof or may be obtained from foreign sources. Any polyadenylation sequence which is functional in the algal host of choice may be used in the present invention.

The procedures used to ligate the elements described above to construct the recombinant expression vector of the

present invention are well known to one skilled in the art (see, for example, Sambrook, 2nd ed., et al., *Molecular Cloning, A Laboratory Manual* Cold Spring Harbor, N.Y., (1989), herein incorporated by reference in its entirety).

The present invention also relates to recombinant algal host cells produced by the methods of the present invention which are advantageously used with the recombinant vector of the present invention. The cell is preferably transformed with a vector comprising a nucleic acid sequence of the invention followed by integration of the vector into the host chromosome. The choice of algal host cells will to a large extent depend upon the gene encoding the protein or fragment thereof and its source.

Algal cells may be transformed by a variety of known techniques, including but not limited to, microprojectile bombardment, protoplast fusion, electroporation, microinjection, and vigorous agitation in the presence of glass beads. Suitable procedures for transformation of green algal host cells are described in EP 108 580, herein incorporated by reference in its entirety. A suitable method of transforming *Chlorella* species is described by Jarvis and Brown, *Curr. Genet.* 19: 317-321 (1991), herein incorporated by reference in its entirety. A suitable method of transforming cells of diatom *Phaeodactylum tricorutum* species is described in WO 97/39106, herein incorporated by reference in its entirety. Chlorophyll C-containing algae may be transformed using the procedures described in U.S. Pat. No. 5,661,017, herein incorporated by reference in its entirety.

The expressed protein or fragment thereof may be detected using methods known in the art that are specific for the particular protein or fragment. These detection methods may include the use of specific antibodies, formation of an enzyme product, or disappearance of an enzyme substrate. For example, if the protein or fragment thereof has enzymatic activity, an enzyme assay may be used. Alternatively, if polyclonal or monoclonal antibodies specific to the protein or fragment thereof are available, immunoassays may be employed using the antibodies to the protein or fragment thereof. The techniques of enzyme assay and immunoassay are well known to those skilled in the art.

The resulting protein or fragment thereof may be recovered by methods known in the arts. For example, the protein or fragment thereof may be recovered from the nutrient medium by conventional procedures including, but not limited to, centrifugation, filtration, extraction, spray-drying, evaporation, or precipitation. The recovered protein or fragment thereof may then be further purified by a variety of chromatographic procedures, e.g., ion exchange chromatography, gel filtration chromatography, affinity chromatography, or the like.

Computer Readable Media

The nucleotide or amino acid sequence provided in SEQ ID NO: 1 through SEQ ID NO: 626, or fragment thereof, or complement thereof, or a nucleotide or an amino acid sequence at least 70% identical, preferably 90% identical even more preferably 99% or about 100% identical to the sequence provided in SEQ ID NO: 1 through SEQ ID NO: 626, or where appropriate complement thereof or fragments of either, can be "provided" in a variety of mediums to facilitate use. Such a medium can also provide a subset thereof in a form that allows a skilled artisan to examine the sequences.

A further preferred subset of nucleic acid sequences is where the subset of sequences is two proteins or fragments thereof, more preferably three proteins or fragments thereof and even more preferable four proteins or fragments thereof.

In one application of this embodiment, a nucleotide sequence of the invention can be recorded on computer readable media so that a computer-readable medium comprises one or more of the nucleotide sequences of the invention. As used herein, "computer readable media" refers to any medium that can be read and accessed directly by a computer. Such media include, but are not limited to: magnetic storage media, such as floppy discs, hard disc, storage medium and magnetic tape; optical storage media such as CD-ROM; electrical storage media such as RAM and ROM; and hybrids of these categories such as magnetic/optical storage media.

Any number of the sequences, or sequence fragments, of the nucleic acid molecules or proteins of the invention, or fragments of either, can be included, in any number of combinations, on a computer-readable medium. Specifically, any one or more of SEQ ID NO: 1-626, or where appropriate, complements thereof, can be included.

A skilled artisan can readily appreciate how any computer readable medium can be used to create a machine or method comprising a computer readable medium having recorded thereon a nucleotide sequence of the invention. As used herein, "recorded" refers to a process for storing information on computer readable medium. A skilled artisan can readily adopt any method for recording information on computer readable medium to generate media comprising the nucleotide sequence information of the invention. A variety of data storage structures are available to a skilled artisan for creating a computer readable medium having recorded thereon a nucleotide sequence of the invention. The choice of the data storage structure will generally be based on the means chosen to access the stored information. In addition, a variety of data processor programs and formats can be used to store the nucleotide sequence information of the invention on computer readable medium. The sequence information can be represented in a word processing text file, formatted in commercially-available software such as WordPerfect or Microsoft Word, or represented in the form of an ASCII file, stored in a database application, such as DB2, Sybase, Oracle, or the like. A skilled artisan can readily adapt any number of data processor structuring formats (e.g., text file or database) in order to obtain computer readable medium having recorded thereon the nucleotide sequence information of the invention.

By providing one or more of nucleotide sequences of the invention, a skilled artisan can routinely access the sequence information for a variety of purposes. Computer software is publicly available that allows a skilled artisan to access sequence information provided in a computer readable medium. The examples which follow demonstrate how software which implements the BLAST (Altschul et al., *J. Mol. Biol.* 215:403-410 (1990), the entirety of which is herein incorporated by reference) and BLAZE (Brutlag et al., *Comp. Chem.* 17:203-207 (1993), the entirety of which is herein incorporated by reference) search algorithms on a Sybase system can be used to identify open reading frames (ORFs) within the genome that contain homology to ORFs or proteins from other organisms. Such ORFs are protein-encoding fragments within the sequences of the invention and are useful in producing commercially important proteins such as enzymes used in amino acid biosynthesis, metabolism, transcription, translation, RNA processing, nucleic acid and a protein degradation, protein modification and DNA replication, restriction, modification, recombination and repair.

The invention further provides systems, particularly computer-based systems, which contain the sequence infor-

mation described herein. Such systems are designed to identify commercially important fragments of the nucleic acid molecule of the invention. As used herein, "a computer-based system" refers to the hardware means, software means and data storage means used to analyze the nucleotide sequence information of the invention. The minimum hardware means of the computer-based systems of the invention comprises a central processing unit (CPU), input means, output means and data storage means. A skilled artisan can readily appreciate that any one of the currently available computer-based system are suitable for use in the invention.

As indicated above, the computer-based systems of the invention comprise a data storage means having stored therein a nucleotide sequence of the invention and the necessary hardware means and software means for supporting and implementing a search means. As used herein, "data storage means" refers to memory that can store nucleotide sequence information of the invention, or a memory access means which can access manufactures having recorded thereon the nucleotide sequence information of the invention. As used herein, "search means" refers to one or more programs which are implemented on the computer-based system to compare a target sequence or target structural motif with the sequence information stored within the data storage means. Search means are used to identify fragments or regions of the sequence of the invention that match a particular target sequence or target motif. A variety of known algorithms are disclosed publicly and a variety of commercially available software for conducting search means are available can be used in the computer-based systems of the invention. Examples of such software include, but are not limited to, MacPattern (EMBL), BLASTIN and BLASTIX (NCBIA). One of the available algorithms or implementing software packages for conducting homology searches can be adapted for use in the present computer-based systems.

The most preferred sequence length of a target sequence is from about 10 to 100 amino acids or from about 30 to 300 nucleotide residues. However, it is well recognized that during searches for commercially important fragments of the nucleic acid molecules of the invention, such as sequence fragments involved in gene expression and protein processing, may be of shorter length.

As used herein, "a target structural motif," or "target motif," refers to any rationally selected sequence or combination of sequences in which the sequences the sequence (s) are chosen based on a three-dimensional configuration which is formed upon the folding of the target motif. There are a variety of target motifs known in the art. Protein target motifs include, but are not limited to, enzymatic active sites and signal sequences. Nucleic acid target motifs include, but are not limited to, promoter sequences, cis elements, hairpin structures and inducible expression elements (protein binding sequences).

Thus, the invention further provides an input means for receiving a target sequence, a data storage means for storing the target sequences of the invention sequence identified using a search means as described above and an output means for outputting the identified homologous sequences.

A variety of structural formats for the input and output means can be used to input and output information in the computer-based systems of the invention. A preferred format for an output means ranks fragments of the sequence of the invention by varying degrees of homology to the target sequence or target motif. Such presentation provides a skilled artisan with a ranking of sequences which contain various amounts of the target sequence or target motif and identifies the degree of homology contained in the identified fragment.

A variety of comparing means can be used to compare a target sequence or target motif with the data storage means to identify sequence fragments sequence of the invention. For example, implementing software which implement the BLAST and BLAZE algorithms (Altschul et al., *J. Mol. Biol.* 215:403410 (1990)) can be used to identify open frames within the nucleic acid molecules of the invention. A skilled artisan can readily recognize that any one of the publicly available homology search programs can be used as the search means for the computer-based systems of the invention.

Having now described the invention, the following examples are provided by way of illustration and are not intended to limit the scope of the invention, unless specified.

EXAMPLE 1

Identification of Yeast HES1

The yeast strain LPY9 (MATa, leu2, Ura3, his3) is grown overnight and inoculated into SD+ hul (histidine, uracil, leucine) media. Aliquots of the culture are treated with ketoconazole (an inhibitor of C-14 α demethylase (P450_{14DM}) enzyme) at 10 ug/ml, 50 ug/ml, and 100 ug/ml, corresponding to 10 ppm, 50 ppm, and 100 ppm, respectively. A sample of each is collected at 2, 4, and 6 hours after treatment. Control samples treated with DMSO (dimethyl sulfoxide-solvent for ketoconazole) but not with ketoconazole are also collected. Total RNA from each sample is collected by conventional methods, such as a Zirconium/Silica bead binding and extraction method. The sequence content of each sample is analyzed and compared by hybridizing each of them to a number of yeast ORF sequences immobilized on a Nylon membrane in an array format.

A similar comparison of a wild type yeast strain and a double mutant strain is made. The double mutant CJ517 (MATa, erg11::URA3, erg3::LEU2, leu2, ura3, his4) [erg11, erg3 double mutant] is compared to LPY9 after growth in both YPD and SD+hul media. Samples are collected at approximately 0, 2, 4, and 6 hours after inoculation.

Table 2, below, lists the RNAs in each sample whose abundance is effected by ketoconazole treatment or whose abundance differs between wild type and the double mutant strain. The table also lists the corresponding gene or sequence identifier for those RNAs. The RNAs are ranked by the ratio of either ketocanzole vs. control or mutant vs. control, using the ratio of 50 ppm ketocanzole/control as a basis for comparison.

TABLE 2*

Seq. Num. Clone ID	ALIAS	CJ-4hr/ LP-4hr	K-50/CK	K-100/CK	Gene Description
30 YOR237W	(HES1)	134.648161	1417.6262	1358.1235	Protein implicated in ergosterol biosynthesis, member of the KES1/HES1/OSH1/YKR003W family of oxysterol-binding (OSBP) proteins

TABLE 2*-continued

Seq. Num.	Clone ID	ALIAS	CJ-4hr/ LP-4hr	K-50/CK	K-100/CK	Gene Description
31	YKL198C	(PTK1)	68.5845326	111.1984	233.11762	Serine/threonine protein kinase, activator of low-affinity, low-capacity polyamine transport
32	YLR465C	—	97.9601498	104.52215	133.57826	Protein of unknown function, questionable ORF
33	YMR129W	(POM152)	5.10206225	82.813831	15.392788	Nuclear pore membrane glycoprotein, type II integral membrane protein with N-terminal region on pore side and C-terminal region in the cisternae
34	YBR284W	—	4.92774291	60.027955	8.5359554	Protein with similarity to AMP deaminase
35	YKL158W	—	11.6717854	59.827307	75.220412	Protein of unknown function
36	YOR083W	—	31.7378598	51.606081	42.301568	Protein of unknown function
37	YOL095C	—	3.60507866	49.740211	21.834188	Protein with similarity to <i>S. aureus</i> DNA helicase PCRA
38	YOR188W	(MSB1)	2.19997209	42.446767	61.303817	Protein that may play a role in polarity establishment and bud formation
39	YBL109W	—	0.08616121	38.653463	75.964757	—
40	YLR091W	—	17.5946744	38.325073	44.556481	Protein of unknown function
41	YNL106C	(INP52)	2.52986454	35.205536	17.376557	—
42	YDR213W	—	18.2079478	32.136065	58.358612	Protein with similarity to transcription factors, has ZN[2]-CYS[6] fungal-type binuclear cluster domain in the N-terminal region
43	YBL004W	—	8.49387973	28.614573	28.645633	Protein with similarity to members of the major facilitator superfamily (MFS)
44	YIR019C	(MUC1)	48.7538739	27.594853	137.77885	Glucosylase 1 (alpha-1,4-glucan glucosidase), extracellular enzyme
45	YIL182C	—	2.53469593	26.891434	29.499298	Protein of unknown function
46	YMR254C	—	0.19897977	26.633459	10.625738	Protein of unknown function, questionable ORF
47	YDL134C	(PPH21)	3.51284473	22.849241	0	—
48	YCR098C	(GIT1)	2.27672091	21.746838	24.724171	Protein involved in inositol metabolism
49	YPL150W	—	4.72964069	21.633895	34.40982	Serine/threonine protein kinase of unknown function
50	YKL110C	(KTI12)	19.7752946	21.085633	16.303432	Protein involved in resistance to <i>kluyveromyces lactis</i> killer toxin
51	YER011W	(TIR1)	31.4723195	20.454605	17.935906	Stress-induced cell wall structural protein of the PAU1 family
52	YDL024C	—	3.96163383	20.381493	30.488098	Protein with similarity to acid phosphatases
53	YGR013W	—	0.10491681	20.364081	0	—
54	YOR325W	—	47.3518002	20.211317	29.305064	Protein of unknown function
55	YJR150C	—	159.265973	19.793221	13.560079	—
56	YDL126C	(CDC48)	42.7590386	19.0472	15.014024	Protein of the AAA family of ATPases, required for cell division and homotypic membrane fusion
57	YLR464W	—	12.4297115	18.580843	36.516503	Protein with similarity to other subtelomerically-coded proteins
58	YLR124W	—	0.13902212	18.351487	11.026125	Protein of unknown function
59	YLR463C	—	8.49721471	18.007814	29.811632	Protein with similarity to other subtelomerically-coded proteins
60	YMR297W	(PRC1)	6.20117404	17.995865	24.291751	Carboxypeptidase Y (CPY) (YSCY), serine-type protease
61	YFL029C	(CAK1)	17.1104765	16.96782	44.352291	CDK-activating kinase (serine/threonine protein kinase) responsible for in vivo activation of CDC28P, also involved in spore wall formation
62	YER054C	(GIP2)	2.14214491	16.442373	15.284537	GLC7P-interacting protein, possible regulatory subunit for the PP1 family protein phosphatase GLC7P
63	YER060W-A	(FCY22)	2.61677424	15.768882	20.550953	Purine-cytosine permease with similarity to FCY2P, member of the purine/cytosine family of the major facilitator superfamily (MFS)
64	YEL076C	—	13.7918147	14.372278	26.325282	Protein with similarity to other subtelomerically-encoded proteins
65	YGL176C	—	9.0823019	14.17085	16.23816	Protein with similarity to discopyge OMMATA CA++ channel alpha 1 subunit protein B47447
66	YNR005C	—	12.9230524	14.032659	13.011356	Protein of unknown function, questionable ORF
67	YML032C-A	—	6.92372404	13.847081	5.501802	—
68	YGR190C	—	22.9885796	13.701633	42.22779	Protein of unknown function
69	YHR213W	—	17.3140804	13.267403	21.010074	Protein with similarity to the N-terminus of FLO1P and identical to YAR062P, probable pseudogene

TABLE 2*-continued

Seq. Num.	Clone ID	ALIAS	CJ-4hr/ LP-4hr	K-50/CK	K-100/CK	Gene Description
70	YPL272C	—	24.778114	12.93877	11.647985	Protein of unknown function
71	YBL100C	—	4.8456884	12.432421	16.193059	Protein of unknown function
72	YLR024C	—	11.2130442	11.927798	17.73046	Protein with similarity to ubiquitin-protein ligase (E3) UBR1P
73	YMR102C	—	4.61311719	11.865115	16.370862	—
74	YGR177C	(ATF2)	3.7081426	11.830169	12.555269	Alcohol O-acetyltransferase
75	YFR034C	(PHO4)	14.8112083	11.216073	20.844515	Basic helix-loop-helix (BHLH) transcription factor required for expression of phosphate pathway, hyperphosphorylation by PHO80P-PHO85P cyclin-dependent protein kinase complex causes inactivation
76	YNL282W	—	5.01708646	10.943286	13.050614	—
77	YPL176C	—	7.30789994	10.664169	18.424583	Protein with similarity to SSP134P
78	YMR015C	(ERG5)	10.2651358	10.313689	9.3557963	Cytochrome P450 (C-22 sterol desaturase)
79	YCR061W	—	4.07462743	10.291287	12.602668	Protein of unknown function
80	YHL030W	(ECM29)	4.85453872	10.275837	8.9818305	Protein possibly involved in cell wall structure or biosynthesis
81	YPL036W	(PMA2)	7.19300398	10.171951	12.917306	H ⁺ -transporting P-type ATPase of the plasma membrane, expression not detected under normal growth conditions
82	YFR007W	—	2.58144987	10.102403	6.0105766	Protein of unknown function
83	YOL067C	(RTG1)	30.4142081	10.027065	27.36633	Basic helix-loop-helix (BHLH) transcription factor involved in inter-organelle communication between mitochondria, peroxisomes, and nucleus
84	YGR265W	—	22.156977	9.9554618	5.672919	Protein of unknown function
85	YGR293C	—	51.4998515	9.7686634	8.066486	Protein of unknown function
86	YMR008C	(PLB1)	5.68517668	9.602215	11.309345	Phospholipase B (lysophospholipase), releases fatty acids from lysophospholipids
87	YOR140W	—	6.33829162	9.2015298	12.881145	—
88	YML034W	—	4.44092944	9.2011248	15.848216	Protein of unknown function
89	YGR176W	—	4.56487981	8.8866015	12.598661	Protein of unknown function
90	YOR014W	(RTS1)	7.03478812	8.8422619	11.590438	Protein serine/threonine phosphatase 2A (PP2A), B' regulatory subunit, involved in regulation of stress-related responses and the cell cycle
91	YMR317W	—	25.9636363	8.6834125	11.973301	Protein of unknown function
92	YOR301W	—	11.3702021	8.6327901	13.589223	Protein of unknown function
93	YER119C-A	—	8.9509545	8.4086333	6.8517264	—
94	YOR385W	—	6.30021483	8.3714543	10.537348	Protein of unknown function
95	YGL156W	(AMS1)	11.9450551	8.2732125	9.9190578	Alpha-mannosidase, hydrolyzes terminal non-reducing alpha-D-mannose residues from alpha-D-mannosides
96	YJL219W	(HXT9)	6.10093958	8.1969449	14.860533	Hexose transporter, member of the sugar permease family
97	YFL053W	—	3.55404282	8.1217569	6.04425	—
98	YNL279W	—	2.75618909	8.0041323	12.470971	Protein of unknown function
99	YHR007C	(ERG11)	5.511691	7.8623796	8.6320676	Cytochrome P450 (lanosterol 14alpha-demethylase), essential for biosynthesis of ergosterol
100	YJL127C	(SPT10)	4.01528284	7.8394427	10.096027	Protein that amplifies the magnitude of transcriptional regulation at various loci
101	YPL044C	—	2.61973879	7.8291062	4.5399013	Protein of unknown function
102	YOR030W	(DFG16)	4.97362211	7.8182123	10.573213	Protein involved in invasive growth upon nitrogen starvation
103	YIL011W	—	4.59710634	7.3954743	6.7112038	Protein with similarity to YIL176P, YIR041P and other members of the PAU1 family
104	YNR069C	—	14.3161508	7.3694614	14.104044	Protein of unknown function
105	YNL083W	—	2.06305137	7.3050052	15.674556	Protein of the mitochondrial carrier (MCF) family
106	YJL020C	—	6.76775321	7.0352757	5.3432583	Protein of unknown function
107	YFL065C	—	13.5712126	7.0075571	16.704839	Protein with similarity to other subtelomerically-encoded proteins including YHL049P, YIL177P, YJL225P, YER190P, YHR218P, and YEL076P
108	YNL329C	(PAS8)	3.75487269	6.7699941	25.980939	—
109	YHR006W	(STP2)	6.44648003	6.5480808	9.270283	Protein involved in tRNA splicing and branched-chain amino acid uptake
110	YJL221C	(FSP2)	2.37104879	6.4365653	6.3055084	Protein with similarity to alpha-D-glucosidase (maltase) (FSP2 and YIL172C code for identical proteins) (YIL172C and YGR287C are nearly identical)

TABLE 2*-continued

Seq. Num.	Clone ID	ALIAS	CJ-4hr/ LP-4hr	K-50/CK	K-100/CK	Gene Description
111	YMR037C	(MSN2)	6.80686734	6.4235969	7.6612989	Zinc-finger transcriptional activator for genes involved in the multistress response and genes regulated through SNF1P
112	YLR379W	—	6.34038543	6.4227358	6.8206953	Protein of unknown function
113	YLR056W	(ERG3)	0.03858406	6.2735601	5.191422	C-5 sterol desaturase, an iron non-heme oxygen-requiring enzyme of the ergosterol biosynthesis pathway
114	YMR319C	(FET4)	3.5515443	0.2641804	8.194608	Low-affinity Fe(II) transport protein
115	YBR045C	(GIP1)	5.88011982	6.254107	3.8135044	GLC7P-interacting protein, possible regulatory subunit for the PP1 family protein phosphatases GLC7P
116	YKL147C	—	4.54862611	6.2431328	10.034699	Protein of unknown function
117	YMR135W-A	—	15.3287997	6.1049555	4.611173	—
118	YCR048W	(ARE1)	9.11370518	6.1039374	10.531291	Acyl-CoA:sterol acyltransferase (sterol-ester synthetase)
119	YBR235W	—	2.65851474	6.1026186	2.9854465	Protein with similarity to human SLC12A1 gene for which mutations are the cause of Bartier's Syndrome
120	YJL160C	—	5.14571281	6.0795621	6.0193217	Protein with similarity to members of the PIR1P/HSP150P/PIR3P family
121	YNL287W	(SEC21)	5.55890054	6.0742978	5.8985117	Coatomer complex gamma chain (gamma-COP) of secretory pathway vesicles, required for retrograde Golgi to endoplasmic reticulum transport
122	YLR458W	—	28.2501296	5.9435623	4.6311951	—
123	YLR121C	—	4.04284936	5.9154936	8.131848	—
124	YLR347C	(KAP95)	3.84797845	5.8759152	6.4154978	Karyopherin-beta, acts to target proteins with nuclear localization (NLS) sequences to the nuclear pore complex
125	YDL023C	—	3.26329833	5.8589624	4.7058193	Protein of unknown function
126	YAL010C	(MDM10)	5.34077952	5.807758	8.9195451	Protein involved in mitochondrial morphology and inheritance, mutant has large spherical mitochondria that do not move into the bud
127	YDR077W	(SED1)	3.30340602	5.6959082	5.9206909	Abundant cell surface glycoprotein, overexpression suppresses growth defect of ERD2
128	YDR247W	—	3.28497642	5.6793015	6.7651448	Serine/threonine protein kinase with similarity of <i>S. pombe</i> RAN1 negative regulator of sexual conjugation and meiosis (GB:Z49701)
129	YBL011W	—	3.59243122	5.650363	8.393684	—
130	YDL025C	—	2.91426204	5.5604876	3.9241843	Serine/threonine protein kinase with similarity to members of the NPR1 subfamily
131	YAL013W	(DEP1)	8.79366086	5.5463386	6.42501	Regulator of phospholipid metabolism
132	YIL084C	(SDS3)	1.99582364	5.5430688	6.9074225	Suppressor of silencing defect
133	YJL213W	—	7.09632444	5.4980741	5.5079382	Protein with weak similarity to nocardia arylalkylphosphatase
134	YKR053C	—	5.37724431	5.4952302	6.4562635	—
135	YNR042W	—	17.7115615	5.4798109	7.5527661	Protein of unknown function
136	YCR072C	—	5.34712592	5.4565375	4.5985045	Protein with similarity to nuclear mRNA processing protein PRP4P, member of WD (WD-40) repeat family
137	YER086W	(ILV1)	4.55278717	5.4449008	4.2437712	Serine and threonine dehydratase (anabolic), first step in isoleucine biosynthesis pathway
138	YJL076W	—	11.4128793	5.4277219	6.6898119	—
139	YLR072W	—	5.19287856	5.4152299	7.2827024	Protein of unknown function
140	YDR301W	(YHH1)	2.51614995	5.4121298	7.0975432	—
141	YIL055C	—	2.0005314	5.3410327	4.6542324	Protein of unknown function
142	YEL076W-C	—	13.2032684	5.3265661	8.0731692	—
143	YNR047W	—	4.44731559	5.3217828	6.1790659	Serine/threonine protein kinase of unknown function
144	YGL211W	—	4.00934024	5.2957602	5.5379668	Protein of unknown function
145	YGL012W	(ERG4)	4.57738431	5.2945042	4.833773	Sterol C-24 reductase
146	YCL014W	(BUD3)	2.0970839	5.2855114	3.3963317	Protein localized at the neck filament ring required for axial budding, may provide a memory of the previous bud site
147	YBR106W	—	5.74228482	5.2537051	9.2061479	—
148	YHR095W	—	5.25923706	5.2434619	2.2666062	Protein of unknown function
149	YEL010W	—	3.39547744	5.2424909	3.9026395	Protein of unknown function
150	YBR005W	—	5.58242328	5.2283592	7.5591013	Protein of unknown function
151	YPL183C	—	3.25331232	5.2150911	4.034456	Protein of unknown function, has WD (WD-40) repeats
152	YJL159W	—	5.95901062	5.2095163	5.0420867	—
153	YBL065W	—	5.04084137	5.1918263	10.287249	Protein of unknown function
154	YDL071C	—	7.24874297	5.1844239	7.5184825	Protein of unknown function

TABLE 2*-continued

Seq. Num.	Clone ID	ALIAS	CJ-4hr/ LP-4hr	K-50/CK	K-100/CK	Gene Description
155	YGR197C	(SNG1)	6.43784806	5.17339	7.8870948	Probable transport protein that confers resistance to MNNG and nitrosoguanidine
156	YLL028W	—	9.27382002	5.0519624	5.3421753	Member of major facilitator superfamily (MFS) multidrug-resistance (MFS-MDR) protein family
157	YKR034W	(DAL80)	3.91750209	5.0436172	7.2838566	GATA-type zinc finger transcriptional repressor for allantoin and 4-aminobutyric acid (GABA) catabolic genes
158	YDR430C	—	2.19022255	5.0401778	3.1989703	Protein with similarity to Class 1 family of aminoacyl-TRNA synthetases
159	YPL274W	—	5.4156341	5.0164198	6.1307085	Protein with similarity to GAP1P and other amino acid permeases
160	YMR261C	(TPS3)	3.96385669	4.94376	3.7501015	Component of the trehalose-6-phosphate synthase/phosphatase complex, alternate third subunit with TLS1P
161	YOL118C	—	3.20265396	4.936553	5.7544219	Protein of unknown function
162	YOR005C	(DNL4)	4.47086248	4.8815521	3.6707508	ATP-dependent DNA ligase IV, involved in non-homologous DNA end joining
163	YNL332W	—	3.33896215	4.8789948	4.7570682	—
164	YDR069C	(DOA4)	3.37810593	4.8769723	5.1947947	Ubiquitin-specific protease (ubiquitin C-terminal hydrolase) of the 26S proteasome complex, involved in vacuole biogenesis and osmoregulation
165	YOR009W	—	59.4543494	4.8708102	5.2948993	Protein with similarity to members of the PAU1 family
166	YMR035W	(IMP2)	9.23409301	4.8492871	5.7664813	Inner membrane protease of mitochondria, acts in complex with IMP1P but has different substrate specificity for removal of signal peptidase
167	YER089C	(PTC2)	2.23920866	4.8455014	5.8687657	Protein serine/threonine phosphatase of the PP2C family
168	YJR018W	—	5.54754057	4.8389334	4.4934937	Protein of unknown function
169	YLR088W	(GAA1)	3.1893544	4.814116	4.0142997	Protein required for attachment of GPI anchor onto proteins, affects endocytosis
170	YOL163W	—	3.92239312	4.8014959	4.5124682	Protein with weak similarity to pseudomonas putida phthalate transporter
171	YLR462W	—	3.32915042	4.7928645	7.1350658	Protein of unknown function
172	YLR098C	(CHA4)	2.05280928	4.7564347	5.5866465	Zinc-finger protein required for activation of CHA1, has A ZN[2]-CYS[6] fungal-type binuclear cluster domain
173	YNR053C	—	2.55991235	4.7234659	3.8186389	Protein with similarity to human breast tumor-associated autoantigen
174	YDL246C	—	2.43826188	4.6757263	3.5757353	Protein with similarity to SOR1P (SOR1 and YDL246C code for nearly identical proteins)
175	YOL045W	—	3.55662236	4.672513	2.0538279	Serine/threonine protein kinase of unknown function
176	YKL176C	—	3.32695888	4.6429893	5.4538239	Protein of unknown function
177	YJR114W	—	3.00664482	4.6389866	4.0045917	Protein of unknown function
178	YER091C	(MET6)	6.67067887	4.6224571	2.9292597	Homocysteine methyltransferase (5-methyltetrahydropteroyl triglutamate-homocysteine methyltransferase), methionine synthase, cobalamin-independent
179	YHL049C	—	5.15537247	4.5637645	9.5066446	Protein with similarity to other subtelomerically-encoded proteins including YER189P, YML133P, and YJL225P, coded from a subtelomeric Y' region
180	YDR389W	(SAC7)	3.89197011	4.5609599	4.3143109	GTPase-activating protein for RHO1P
181	YMR202W	(ERG2)	9.58572292	4.5446614	5.575174	Sterol C8-C7 isomerase (C-8 sterol isomerase), enzyme of the ergosterol biosynthesis pathway
182	YBL019W	—	3.45990928	4.4694518	4.1655454	—
183	YGR287C	—	10.2933872	4.4595137	9.7718104	Protein with similarity to alpha-D-glucosidase (maltase) (YGR287CIS nearly identical to FSP2 and YIL172C)
184	YJL082W	—	7.42175571	4.4522595	5.556901	Protein of unknown function
185	YHR098C	—	2.51284975	4.4353768	4.3716652	Protein of unknown function
186	YOR371C	—	2.47743776	4.4289864	5.2783501	Protein of unknown function
187	YDR530C	(APA2)	2.40849553	4.3993312	2.7389073	ATP adenyllyltransferase II (AP4A phosphorylase)
188	YKL119C	(VPH2)	0.16462534	4.3613346	0	Vacuolar H-ATPase (V-ATPase) assembly protein acting in the endoplasmic reticulum
189	YOR273C	—	13.0544715	4.3469302	10.649131	Protein with similarity to members of major facilitator superfamily (MFS) multidrug-resistance (MFS-MDR) protein family

TABLE 2*-continued

Seq. Num.	Clone ID	ALIAS	CJ-4hr/ LP-4hr	K-50/CK	K-100/CK	Gene Description
190	YPL042C	(SSN3)	6.78272968	4.3344728	3.9578568	Cyclin-dependent serine/threonine protein kinase of the RNA polymerase II holoenzyme complex and Kornberg's mediator (SRB) subcomplex
191	YGR268C	—	4.77373538	4.3329069	5.2744105	Protein of unknown function
192	YPR011C	—	2.0077462	4.3123349	4.2742986	Protein with similarity to human Grave's Disease carrier protein (SP:P16260) and to bovine homolog of Grave's Disease carrier protein (SP:Q01888)
193	YPL022W	(RAD1)	4.48327554	4.3036056	6.5285426	Component of the nucleotide excision repairosome, homolog of human XPF xeroderma pigmentosum gene product and the mammalian ERCC-4 protein
194	YGL207W	(SPT16)	5.34289635	4.3033021	3.5727713	General chromatin factor required for adequate expression of CLN and other genes
195	YGL167C	(PMR1)	4.12359747	4.2628564	4.8141347	CA ⁺⁺ -transporting P-type ATPase of Golgi membrane involved in CA ⁺⁺ import into Golgi
196	YJR091C	(JSN1)	4.56429439	4.2419881	4.7804157	Protein that when overexpressed can suppress the hyperstable microtubule phenotype of TUB2-150
197	YDR238C	(SEC26)	4.48641405	4.2179222	3.8109695	Coatamer complex beta chain (beta-COP) of secretory pathway vesicles, required for retrograde transport from Golgi to endoplasmic reticulum
198	YDL012C	—	2.90930997	4.2158147	2.0519798	Protein of unknown function
199	YDR044W	(HEM13)	14.9283272	4.2136787	3.4946018	Coproporphyrinogen III oxidase, oxygen-repressed, sixth step in heme-biosynthetic pathway
200	YGL114W	—	3.22707938	4.2023503	5.0073787	Protein with similarity to <i>S. pombe</i> ISP4 protein, member of the major facilitator superfamily (MFS)
201	YGL055W	(OLE1)	2.29875509	4.1923045	3.5992372	Stearoyl-CoA desaturase (delta-9 fatty acid desaturase), required for synthesis of unsaturated fatty acids
202	YDL088C	(ASM4)	4.39685251	4.1757265	3.321034	Suppressor of temperature-sensitive mutations in POL3P (DNA polymerase delta)
203	YKL171W	—	2.64137608	4.1581147	8.2933538	Serine/threonine protein kinase of unknown function
204	YPL190C	—	5.94196213	4.1575162	3.202837	—
205	YMR140W	—	5.24432896	4.157179	5.4545409	Protein of unknown function
206	YBL005W	(PDR3)	3.75060207	4.1449054	6.0827305	Transcription factor related to PDR1P, contains a ZN[2]-CYS[6] fungal-type binuclear cluster domain in the N-terminal region
207	YML032C	(RAD52)	3.13968668	4.1330793	3.0832115	Protein required for recombination and repair of X-ray damage, has a late function in meiotic recombination
208	YFR018C	—	5.28886874	4.1041589	6.4001917	Protein with similarity to human glutaminyl-peptide cyclotransferase
209	YGL125W	(MET11)	6.80542292	4.0762178	4.4382484	—
210	YCR057C	(PWP2)	3.34704165	4.0555292	3.4118145	—
211	YBL044W	—	4.67885642	4.0526493	9.1998322	Protein of unknown function
212	YPL268W	(PLC1)	2.90633764	4.0372127	2.1993847	Phosphoinositide-specific phospholipase C (1-phosphatidylinositol-4,5-bisphosphate phosphodiesterase 1), produces diacylglycerol and inositol 1,4,5-trisphosphate
213	YOR204W	(DED1)	2.52920945	4.0291663	3.0830731	ATP-dependent RNA helicase of dead box family involved in protein synthesis
214	YPL171C	(OYE3)	4.94122983	4.0225239	0.2747214	NAPDH dehydrogenase (old yellow enzyme), isoform 3
215	YOR203W	—	3.473713	3.9900922	3.2232019	Protein of unknown function
216	YNL295W	—	2.855052	3.9889367	2.1389666	Protein of unknown function
217	YEL042W	(GDA1)	2.00067395	3.9856733	3.8058139	Guanosine diphosphatase of Golgi membrane
218	YLR339C	—	4.12619065	3.9844972	3.506939	Protein of unknown function
219	YIL007C	—	5.11957134	3.9770005	2.318674	Protein of unknown function
220	YIR007W	—	3.71972069	3.9670484	5.0861072	Protein with similarity to endoglucanase
221	YER114C	(BOI2)	2.5967273	3.9643546	6.3042836	Protein with SH3 domain involved in bud formation, binds to BEM1P
222	YLR092W	(SUL2)	6.02237117	3.9547891	4.5438793	High-affinity sulfate transporter
223	YEL060C	(PRB1)	5.60961951	3.939317	4.7370327	Protease B (YSCB) (PRB) (cerevisin), serine protease of the subtilisin family with broad proteolytic specificity

TABLE 2*-continued

Seq. Num.	Clone ID	ALIAS	CJ-4hr/ LP-4hr	K-50/CK	K-100/CK	Gene Description
224	YAL051W	—	2.40553928	3.9334781	4.5099518	—
225	YJR147W	—	2.05911726	3.9267937	5.1956856	—
226	YOR386W	(PHR1)	1.99823774	3.9204076	5.7090569	Deoxyribodipyrimidine photolyase, involved in light-dependent repair of pyrimidine dimers
227	YCR037C	(PHO87)	2.81200613	3.8982171	4.0311884	Member of the phosphate permease family of the major facilitator superfamily
228	YOL100W	—	3.04632994	3.8854218	9.2592192	Serine/threonine protein kinase of unknown function
229	YBL047C	—	3.40597241	3.88363	5.2814809	Protein with similarity to cytoskeletal protein USO1P, PAN1P, and mouse tyrosine kinase substrate EPS15
230	YAR014C	—	2.53512963	3.823947	4.4065791	Protein of unknown function
231	YKL182W	(FAS1)	3.75368336	3.8068781	5.3493259	Fatty-acyl-CoA synthase, beta chain (contains acetyl transferase, enoyl reductase, dehydratase, and malonyl/palmitoyl transferase)
232	YLR331C	—	3.94099666	3.795387	3.3715843	Protein of unknown function
233	YEL031W	(SPF1)	7.77512435	3.7891074	4.357615	Protein with similarity to CA++-transporting ATPases
234	YHR078W	—	2.2941334	3.7838221	4.6151917	Protein of unknown function, has 4 potential transmembrane domains
235	YPL155C	(KIP2)	3.29502679	3.7807978	9.392792	Kinesin-related protein
236	YNR074C	—	4.3061075	3.7638306	5.7991531	Protein with similarity to <i>Bacillus subtilis</i> nitrite reductase (NIRB)
237	YMR303C	(ADH2)	4.56919214	3.7542967	3.1957867	Alcohol dehydrogenase II, glucose-repressed
238	YLR134W	(PDC5)	4.9450653	3.7528169	3.2704832	Pyruvate decarboxylase isozyme 2
239	YKL067W	(YNK1)	4.49102455	3.7325797	3.6497934	Nucleoside diphosphate kinase, responsible for synthesis of all nucleoside triphosphates except ATP
240	YLR136C	(TIS11)	2.88004451	3.7255421	5.1711798	—
241	YDR443C	(SCA1)	2.75733315	3.7068432	6.9331513	—
242	YGL071W	(RCS1)	3.39203358	3.6963077	4.5310166	Regulatory protein involved in IRON uptake
243	YBR293W	—	2.25740646	3.6840827	3.0384171	Member of major facilitator superfamily (MFS) multidrug-resistance (MFS-MDR) protein family
244	YMR324C	—	3.33053542	3.6802526	2.8779503	Protein with similarity to members of the YBL108P/YCR103P/YKL223P family
245	YFL051C	—	2.07690974	3.6611179	4.7476201	Protein with similarity to FLO1P family of proteins
246	YBR276C	(PPS1)	2.35950244	3.6550406	3.4539593	Protein tyrosine phosphatase (PTPase) with dual specificity
247	YFL042C	—	3.57726533	3.6509118	4.5694594	Protein of unknown function, has similarity to YHR080P
248	YPL203C	(KEL3)	4.50871509	3.6484792	3.8498382	Protein with similarity to KEL1P and KEL2P
249	YLR188W	(MDL1)	5.00498919	3.6475982	4.3936321	ATP-binding cassette (ABC) superfamily member, equivalent to a "half-molecule" ABC protein plus an ATP-binding domain
250	YPR021C	—	2.21061647	3.6466639	3.2312479	Protein with similarity to proteins of the mitochondrial carrier (MCF) family (GB:Z49274)
251	YKL138C	(MRPL31)	3.22538649	3.6454084	4.0488722	Mitochondrial ribosomal protein of the large subunit (YML31)
252	YNL148C	(ALF1)	3.33997835	3.6391378	5.2515594	Alpha-tubulin foldin, cofactor B
253	YLR302C	—	10.5636377	3.6318383	0.3621924	Protein of unknown function
254	YBR298C	(MAL31)	5.44502575	3.6302693	9.8311328	High affinity maltoseH+ symporter (maltose permease) member of the sugar permease family
255	YAR044W	(OSH1)	4.12112011	3.624939	3.8839622	Protein implicated in ergosterol biosynthesis, member of the KES1/HES1/OSH1/YKR003W family of oxysterol-binding (OSBP) proteins
256	YLR120C	(YAP3)	6.14265883	3.6229845	4.4298562	Transcription factor of the basic leucine zipper (BZIP) family, one of eight members of a novel fungal-specific family of BZIP proteins
257	YGR134W	—	2.8756723	3.6189405	1.9505784	Protein of unknown function
258	YMR088C	—	3.01763425	3.574571	2.5742717	Member of major facilitator superfamily (MFS) multidrug-resistance (MFS-MDR) protein family 2
259	YDR291W	—	4.95353348	3.5637613	2.8803997	Protein with similarity to SGS1P and other DNA helicases
260	YJR017C	(ESS1)	2.98118086	3.5587415	3.2208256	Processing/termination factor, involved in transcription termination or 3'-end processing of pre-mRNA
261	YGL178W	(MPT5)	4.28561965	3.558276	3.3338238	Protein required for high temperature growth, recovery from alpha-factor arrest, and normal lifespan of yeast cells

TABLE 2*-continued

Seq. Num.	Clone ID	ALIAS	CJ-4hr/ LP-4hr	K-50/CK	K-100/CK	Gene Description
262	YHR086W	(NAM8)	2.63503306	3.556686	4.1441189	U1 SNRNA-associated protein, essential for meiotic recombination and suppressor of mitochondrial splicing defects, has 3 RNA recognition (RRM) domains
263	YGR178C	(PBP1)	2.95926792	3.5559294	3.6095103	poly(A)-binding protein
264	YBL022C	(PIM1)	4.1993836	3.5255118	3.2518435	Serine protease required for intramitochondrial proteolysis and maintenance of respiratory function, related to <i>E. coli</i> ATP-dependent protease LA
265	YJL083W	—	3.34026267	3.5131828	5.6812601	Protein with similarity to IRS4P
266	YJR053W	—	2.12253894	3.5096202	4.5401439	Protein involved in efficiency of mating
267	YJL175W	—	6.11781731	3.5040684	3.7938536	Protein of unknown function
268	YMR016C	—	3.67893179	3.4720987	3.3111279	—
269	YLL051C	(FRE6)	2.59520796	3.4643555	4.4566151	Protein with similarity to ferric reductase FRE2P
270	YJL212C	—	4.42206996	3.458335	4.0764022	Protein with similarity to <i>S. pombe</i> ISP4+ which is induced by sexual differentiation
271	YMR019W	(STB4)	3.2576922	3.4414621	3.397646	SIN3P-binding protein, has ZN[2]-CYS[6] fungal-type binuclear cluster domain in the N-terminal region
272	YHL047C	—	3.02606918	3.4089434	3.007093	Member of major facilitator superfamily (MFS) multidrug-resistance (MFS-MDR) protein family
273	YBR038W	(CHS2)	2.03060756	3.3885338	2.8509884	Chitin synthase II, responsible for primary septum disk
274	YLR023C	—	2.68880866	3.3876183	2.5555381	Protein of unknown function
275	YPL009C	—	5.28314415	3.3856037	0.8412905	Protein of unknown function
276	YGL008C	(PMA1)	2.09210526	3.3844005	3.725269	H ⁺ -transporting P-type ATPase of the plasma membrane, activity is rate-limiting for growth at low pH
277	YMR033W	(ARP9)	3.08586194	3.3800103	2.9005564	Protein with similarity to actin and actin-related proteins ARP1P-ARP10P
278	YLR153C	(ACS2)	3.45528019	3.3785446	3.1285812	Acetyl-CoA synthetase (acetate-CoA ligase)
279	YLL061W	—	10.9366799	3.369477	3.0795633	Protein with similarity to GAP1P and other amino acid permeases
280	YNL192W	(CHS1)	3.72575719	3.358192	3.7457248	Chitin synthase I, has a repair function during cell separation
281	YEL058W	(PCM1)	4.56623631	3.3482618	3.4456437	Hexosephosphate mutase (phosphoacetylglucosamine mutase) (N-acetylglucosaminophosphate mutase), converts N-acetyl-D-glucosamine 1-phosphate to N-acetyl-D-glucosamine 6-phosphate
282	YLR099C	—	4.72209646	3.3290462	2.9774757	Protein of unknown function
283	YDL057W	—	3.21787484	3.316811	4.4492894	Protein of unknown function
284	YLR195C	(NMT1)	3.4535546	3.3142347	3.1727409	N-myristoyltransferase, adds myristoyl group to N-terminal glycine of certain proteins
285	YAL005C	(SSA1)	3.48582964	3.3068323	2.9388227	Heat shock protein of HSP70 family, cytoplasmic
286	YPL222W	—	2.79485782	3.2974442	2.9997551	Protein of unknown function
287	YJL056C	—	2.36206747	3.2790296	3.3129634	—
288	YKR021W	—	2.33705924	3.269552	2.936447	Protein of unknown function
289	YPL119C	(DBP1)	5.87199247	3.2464223	2.197366	ATP-dependent RNA helicase of dead box family, suppressor SPSS1/DED1
290	YGL014W	—	3.11296478	3.2294295	3.6382821	Protein with pumilio repeats that is involved with MPT5P in relocalization of SIR3P and SIR4P from telomeres to the nucleolus
291	YER010C	—	11.4713039	3.2179542	2.3807886	Protein of unknown function
292	YJR151C	—	41.4229667	3.2130608	4.5216913	Protein of unknown function
293	YPL207W	—	2.48831068	3.2080219	2.9864022	Protein of unknown function
294	YER130C	—	2.01652303	3.2075344	3.3332725	Protein of unknown function
295	YNR065C	—	2.86361451	3.2060768	7.3945002	Protein with similarity to PEP1P
296	YGL192W	(IME4)	2.89030953	3.170381	6.4784105	Positive transcription factor for IME1 and IME2, mediates control of meiosis by carrying signals regarding mating type (A/alpha) and nutritional status
297	YMR047C	(NUP116)	2.56622055	3.1702234	4.7742052	Nuclear pore protein (nucleopurin) of the GLFG family, may be involved in binding and translocation of nuclear proteins
298	YDR256C	(CIA1)	4.54027942	3.158248	8.0093186	Catalase A (peroxisomal)
299	YDR208W	(MSS4)	2.61164524	3.154316	3.0423151	Potential PI P 5-kinase, multicopy suppressor of STT4 mutation

TABLE 2*-continued

Seq. Num.	Clone ID	ALIAS	CJ-4hr/ LP-4hr	K-50/CK	K-100/CK	Gene Description
300	YHR214W	—	4.54013428	3.1513793	5.6325011	Protein of unknown function (YAR066W and YHR214W code for identical proteins)
301	YLR249W	(YEF3)	3.59397167	3.1445334	2.631954	Translation elongation factor EF-3A, member of ATP-binding cassette (ABC) superfamily
302	YNL331C	—	3.44801501	3.1185277	6.5303136	Probable aryl-alcohol reductase
303	YPR115W	—	2.4843458	3.1174643	2.5667848	Protein of unknown function
304	YJL178C	—	2.60257256	3.1121969	2.7705734	Protein of unknown function
305	YAR042W	(SWH1)	18.1940127	3.0992362	6.2488302	Protein of unknown function
306	YDR015C	—	0.09079169	3.0861607	0.3097629	Protein of unknown function
307	YBL067C	(UBP13)	3.41427731	3.0820393	2.4717411	Ubiquitin C-terminal hydrolase
308	YHR072W	(ERG7)	3.5569619	3.0809956	3.4311189	Lanosterol synthase, carries out complex cyclization step of squalene to lanosterol in ergosterol biosynthesis pathway
309	YAL028W	—	9.17485562	3.0726043	3.8109858	Protein of unknown function
310	YIR015W	—	2.80351347	3.066482	3.4328314	Subunit of RNase P
311	YMR308C	(PSE1)	2.69422447	3.0659484	2.6409014	—
312	YOR345C	—	5.73841888	3.0523183	2.2898958	Deoxycytidyl transferase involved in mutagenic translesion DNA synthesis
313	YPL193W	—	3.60415592	3.0500696	2.8450987	Protein of unknown function
314	YFR012W	—	3.31259823	3.0316711	0	Protein of unknown function
315	YPL205C	—	13.258257	3.0208358	0.7999155	Protein of unknown function
316	YDR476C	—	8.1273943	3.0155987	3.8636781	Protein of unknown function
317	YCR052W	(RSC6)	2.2744649	3.0112438	2.6017436	Component of abundant chromatin remodeling complex (RSC)
318	YGL022W	(STT3)	3.64275733	3.0050118	3.8854905	Oligosaccharyltransferase subunit, member of a complex of eight ER proteins that transfers core oligosaccharide from dolichol carrier to Asn-X-Ser/Thr motif
319	YMR109W	—	19.0544656	3.0044499	5.6886658	—
320	YHR032W	—	9.30722933	2.9855823	4.5560581	Protein of unknown function, member of the major facilitator superfamily (MFS)
321	YLR236C	—	2.6190617	2.9810987	3.7681402	—
322	YOR337W	(TEA1)	2.13152473	2.9790715	4.8228581	TY1 enhancer activator of the GAL4P-type family of DNA-binding proteins
323	YFR055W	—	2.35867872	2.9771983	3.0622139	Protein with similarity to <i>E. coli</i> cystathionine beta-lyase
324	YHR212C	—	4.01639255	2.9769438	4.4451423	Protein identical to YAR060P/RAA19P
325	YLR001C	—	2.77031036	2.9663037	2.7628132	Protein of unknown function
326	YOR034C	—	3.38439363	2.9543526	2.5499862	—
327	YPR076W	—	3.86182393	2.9410933	3.2728075	Protein of unknown function
328	YKL183W	—	2.9718977	2.9334031	5.2561547	Protein of unknown function
329	YBR004C	—	3.05485559	2.9257736	2.8905869	Protein expressed between 3 and 6 hours after transfer to sporulation medium
330	YJR071W	—	3.39019477	2.924417	1.768982	Protein of unknown function
331	YCR084C	(TUP1)	2.40138822	2.9219843	3.2718264	General repressor of transcription (with SSN6P), member of WD (WD-40) repeat family
332	YFR030W	(MET10)	33.6060485	2.9138815	2.0879079	Assimilatory sulfite reductase subunit, flavin-binding (alpha) subunit, part of the sulfate assimilation pathway
333	YKL148C	(SDH1)	2.72554507	2.9036242	2.5317298	Succinate dehydrogenase (ubiquinone) flavoprotein (FP) subunit, converts succinate + ubiquinone to fumarate + ubiquinol in the TCA cycle
334	YER044C	—	3.6669641	2.9002716	2.6807728	Protein of unknown function
335	YLR045C	(STU2)	2.16969039	2.8946579	2.9923107	Component of the spindle pole body
336	YPL226W	—	2.45263084	2.8885678	2.5557944	Protein with similarity to members of the ATP-binding cassette (ABC) superfamily
337	YHR161C	—	2.86345744	2.8873374	2.9469349	—
338	YJR109C	(CPA2)	4.31426739	2.8803515	3.1263529	Carbamoylphosphate synthase (glutamine-hydrolyzing) arginine-specific, large chain
339	YGR250C	—	2.20914388	2.8752914	3.8774955	Protein of unknown function, has three RNA recognition (RRM) domains
340	YLR149C	—	3.39994503	2.8694003	4.6627573	Protein of unknown function
341	YCL057W	(PRD1)	3.49569406	2.8641379	2.7495149	Proteinase YSCD, saccharolysin, contains zinc metalloendoprotease motif HEXXH
342	YLR114C	—	2.27233205	2.8496505	1.8650501	Protein with weak similarity in the C-terminus to drosophila melanogaster bicaudal-D protein
343	YML075C	(HMG1)	2.71708812	2.8491957	3.2059005	3-hydroxy-3-methylglutaryl-coenzyme A reductase 1, rate limiting enzyme for sterol biosynthesis, converts HMG-COA to mevalonate

TABLE 2*-continued

Seq. Num.	Clone ID	ALIAS	CJ-4hr/ LP-4hr	K-50/CK	K-100/CK	Gene Description
344	YLR397C	(AFG2)	2.56801854	2.8469125	2.7385515	Protein of the AAA family of ATPases, has similarity to mammalian valosin-containing protein (VCP)
345	YJR019C	(TES1)	4.07777555	2.8303235	2.0724897	Acyl-CoA thioesterase
346	YBL008W	(HIR1)	7.24580603	2.8284713	2.8866813	Histone transcription inhibitor, required for periodic repression of 3 of the 4 histone gene loci and for autogenous repression of HTA1-HTB1 locus by H2A and H2B
347	YGL062W	(PYC1)	2.649771	2.8279558	3.1059191	Pyruvate carboxylase 1, converts pyruvate to oxaloacetate for gluconeogenesis
348	YPL244C	—	3.43385233	2.8218119	3.3274479	Protein of unknown function
349	YGL001C	—	3.91981575	2.8214816	1.9852785	Protein with similarity to nocardia SP. cholesterol dehydrogenase
350	YMR302C	(PRP12)	2.92335545	2.8146501	2.7190981	—
351	YPL160W	(CDC60)	2.25327101	2.8142723	1.7420948	Leucyl-TRNA synthetase, cytoplasmic
352	YLL024C	(SSA2)	4.09160949	2.8142088	2.4784071	Heat shock protein of HSP70 family, cytoplasmic
353	YEL077C	—	3.20718793	2.8098429	3.9054119	—
354	YMR205C	(PFK2)	2.27470363	2.8050429	2.2843952	Phosphofructokinase beta subunit, part of a complex with PFK1P which carries out key regulatory step in glycolysis
355	YPL114W	—	4.16484234	2.7962162	1.717967	Protein of unknown function
356	YPL221W	—	4.08515832	2.7886642	3.960997	Protein of unknown function
357	YJR137C	(ECM17)	26.5435466	2.787597	2.0763181	Putative sulfite reductase (ferredoxin)
358	YKL164C	(PIR1)	2.11125363	2.7864791	2.3925674	Protein required for tolerance to heat shock, member of the PIR1P/HSP150P/PIR3P family
359	YCL037C	(SRO9)	8.35007693	2.7855748	2.393588	Suppressor of YPT6 null and RHO3 mutations
360	YHR082C	(KSP1)	2.14499054	2.7799591	3.4962633	Serine/threonine kinase that suppresses PRP20 mutant when overproduced
361	YPR074C	—	3.19760669	2.7711859	2.476508	—
362	YBR184W	(MEL1)	5.06354303	2.7711448	3.5340388	Alpha-galactosidase (melibiase), converts melibiose into galactose + glucose, converts melibiose to galactose and glucose
363	YOL157C	—	2.70064964	2.7668777	3.6204284	Probable alpha-glucosidase
364	YFL066C	—	2.94443276	2.753026	3.5848427	Protein with similarity to other subtelomerically-encoded proteins including YIL177P, YHL050P, and YER190P
365	YLL029W	—	2.22657399	2.7389102	3.1468025	Protein of unknown function
366	YJL198W	—	2.98124683	2.7343513	4.6395823	Protein with strong similarity to PHO87P, member of the phosphate permease family of the major facilitator, superfamily (MFS)
367	YDR088C	(SLU7)	2.07293165	2.7339627	2.6876744	Pre-mRNA splicing factor affecting 3' splice site choice, required only for the second catalytic step of splicing
368	YJR132W	(NMD5)	3.2005363	2.7333821	3.208398	Member of the karyopherin-beta family, possibly involved in nuclear transport
369	YIL078W	(THS1)	3.31778832	2.7330794	1.6123939	Threonyl-TRNA synthetase, cytoplasmic, member of Class II family of aminoacyl-TRNA synthetases
370	YGL113W	—	2.33404789	2.7249323	3.3810122	Protein of unknown function
371	YMR086W	—	2.69384376	2.7191747	2.9840404	Protein of unknown function
372	YGL233W	(SEC15)	2.61433498	2.7141295	2.7961427	Component of exocyst complex required for exocytosis
373	YGL144C	—	2.26752066	2.7069494	2.6236889	Protein of unknown function
374	YOR137C	—	3.14249753	2.7031211	4.9526236	Protein of unknown function
375	YJR143C	(PMT4)	2.80130312	2.6954799	2.4879264	Mannosyltransferase (dolichyl phosphate-D-mannose:protein O-D-mannosyltransferase), involved in initiation of O-glycosylation
376	YBR289W	(SNF5)	2.00671327	2.6881295	3.038619	Component of SWI/SNF global transcription activator complex, acts to assist gene-specific activators through chromatin remodeling
377	YNL240C	—	5.13894557	2.685901	3.523963	Protein with similarity to kluyveromyces MARX, LET1 protein
378	YML013W	—	3.62672833	2.6831604	2.9292996	Protein of unknown function
379	YKL168C	—	2.43589311	2.6791837	3.1896257	—
380	YGL151W	(NUT1)	2.47823061	2.6787971	2.5683618	Protein that affects expression of HO
381	YNL197C	(WHI3)	2.51493336	2.6764555	3.4233233	Protein involved in regulation of cell size, has 1 RNA recognition (RRM) domain
382	YMR192W	—	2.18376269	2.6732126	2.7489187	Protein with similarity to mouse TBC1 protein
383	YAL038W	(CDC19)	2.63679951	2.6714535	2.7525692	—
384	YEL075C	—	5.12225893	2.6632638	3.778537	Protein with similarity to other subtelomerically-encoded proteins including YHL049P, YIL177P, and YJL225P

TABLE 2*-continued

Seq. Num.	Clone ID	ALIAS	CJ-4hr/ LP-4hr	K-50/CK	K-100/CK	Gene Description
385	YHR219W	—	3.76398139	2.6619567	4.0207342	Protein with similarity to other subtelomerically-encoded proteins
386	YJL069C	—	2.65731007	2.6517254	2.6568606	Protein of unknown function
387	YLR125W	—	6.28348756	2.642933	3.1335402	Protein of unknown function
388	YML035C	(AMD1)	2.23864371	2.6401405	1.6690608	AMP deaminase, converts AMP to IMP and ammonia
389	YMR165C	(SMP2)	2.58642399	2.6310411	3.3572604	Protein whose deletion causes increased plasmid stability
390	YDL223C	—	3.16684859	2.6240147	2.2340877	Protein of unknown function
391	YLR138W	—	2.69090586	2.6158483	2.9821754	—
392	YAR020C	—	3.79173888	2.6111125	2.0234222	—
393	YLR337C	(VRP1)	6.57336326	2.6027011	3.7504037	Proline-rich protein verprolin, involved in cytoskeletal organization and cellular growth
394	YLR060W	(FRS1)	2.61550639	2.5992071	1.9335426	Phenylalanyl-TRNA synthetase, alpha subunit, cytoplasmic
395	YLL013C	—	2.93447915	2.5901954	4.1297767	Protein with similarity to drosophila pumilio protein
396	YIR003W	—	2.41363594	2.5863745	2.874494	Protein with similarity to <i>E. coli</i> and <i>Bacillus subtilis</i> mind, has potential coiled-coil region
397	YIL137C	—	2.27968603	2.5792356	1.9624104	Protein with similarity to aminopeptidases
398	YBL081W	—	2.34404421	2.573205	3.2079939	Protein with 37% identity to drosophila L not protein
399	YOR171C	—	3.59659097	2.5718305	2.4035974	—
400	YPL237W	(SUI3)	2.5966981	2.5628077	2.5479456	Translation initiation factor EIF2beta subunit
401	YHR142W	—	3.52383057	2.5597096	2.9887896	Protein of unknown function
402	YLL012W	—	3.25020683	2.550591	2.7451737	Protein with similarity to human triacylglycerol lipase
403	YFR025C	(HIS2)	2.5112362	2.5457991	2.8789156	Histidinol phosphatase
404	YGR240C	(PFK1)	2.24103063	2.5388997	2.4938739	Phosphofructokinase alpha subunit, part of a complex with PFK2P which carries out A key regulatory step in glycolysis
405	YPL101W	—	4.18961695	2.5351195	2.6201803	Protein of unknown function
406	YOR127W	(RGA1)	3.85804733	2.5316649	2.5697341	RHO-type GTPase-activating protein (GAP) for CDC42P
407	YBR088C	(POL30)	2.5383718	2.5276319	4.0628861	Proliferating cell nuclear antigen (PCNA), required for DNA synthesis and DNA repair
408	YBR295W	(PCA1)	4.16669535	2.525791	1.1221384	P-type copper-transporting ATPase
409	YCL044C	—	2.35958836	2.519608	3.263571	Protein of unknown function
410	YBR110W	(ALG1)	2.23384099	2.5141215	3.2250999	Beta-mannosyltransferase involved in N-glycosylation (transfers MAN from GDP-MAN to DOL-PP-GLCNAC2)
411	YGR175C	(ERG1)	6.02726287	2.5103577	1.8132661	Squalene monooxygenase (squalene epoxidase), enzyme of the ergosterol biosynthesis pathway
412	YLR116W	—	2.98116702	2.5079761	3.9707409	—
413	YCR068W	—	3.32107678	2.4920381	3.6811994	Protein of unknown function
414	YJR105W	—	2.20476096	2.4908887	1.7029385	Protein with similarity to ribokinase
415	YKL157W	(APE2)	2.18209838	2.4866194	2.093134	Aminopeptidase II (YSCII), plays a nutritional role in releasing leucine from peptides externally cleaved at leucine
416	YFR009W	(GCN20)	2.63782118	2.4859544	2.1613378	Component of a protein complex required for activation of GCN2P protein kinase in response to amino acid starvation, member of ATP-binding cassette (ABC) superfamily
417	YDR211W	(GCD6)	2.22567451	2.4835485	1.8240639	Translation initiation factor EIF2B (guanine nucleotide exchange factor), 81 KDA (beta) subunit
418	YAR060C	—	4.88485967	2.482682	4.6114571	Protein identical to YHR212P, has a predicted mitochondrial transit peptide
419	YJL187C	(SWE1)	2.01161328	2.4809757	2.6294797	Serine/tyrosine dual-specificity protein kinase able to phosphorylate CDC28P on tyrosine and inhibit its activity
420	YDR387C	—	2.3225348	2.4746572	3.0481024	Protein with similarity to ITR1P and ITR2P
421	YDR251W	(PAM1)	2.09471237	2.4744652	2.3344613	Coiled-coil protein and multicopy suppressor of loss of PP2A (genes PPH21, PPH22, and PPH3)
422	YJL172W	(CPS1)	2.4464951	2.473092	2.228723	GLY-X carboxypeptidase YSCS, involved in nitrogen metabolism
423	YMR277W	(FCP1)	2.51675116	2.466666	2.2346158	TFIIF-interacting component of the C-terminal domain phosphatase
424	YDL047W	(SIT4)	2.40214863	2.4572974	2.7529791	Protein serine/threonine phosphatase involved in cell cycle regulation, member of the PPP family of protein phosphatases and related to PP2A phosphatases

TABLE 2*-continued

Seq. Num.	Clone ID	ALIAS	CJ-4hr/ LP-4hr	K-50/CK	K-100/CK	Gene Description
425	YML117W	—	2.2473701	2.4482108	2.8054783	Protein of unknown function, contains an ATP/GTP-binding site motif A (P-loop)
426	YHR039C-A	—	2.49103418	2.4469729	1.7368373	—
427	YLL003W	(SFI1)	3.03031186	2.4467012	2.2685901	Protein of unknown function
428	YKR048C	(NAP1)	3.02222721	2.4404483	3.002619	Nucleosome assembly protein that plays a role in assembly of histones into octamer, required for full expression of CLB2P functions
429	YOR197W	—	2.87645711	2.438206	1.9784081	Protein of unknown function
430	YEL046C	(GLY1)	2.40664526	2.4369367	2.6795853	Protein required for glycine prototrophy in SHMT1 SHMT2 double mutant
431	YJL029C	—	2.36823878	2.43429	2.3384644	Protein of unknown function, has similarity to <i>C. elegans</i> hypothetical protein T05G5.8
432	YOR233W	(KIN4)	3.52231883	2.4312627	3.0678435	Serine/threonine protein kinase related to KIN1P and KIN2P, catalytic domain is most related to SNF1P
433	YOR299W	(BUD7)	2.16058794	2.4312223	2.9585581	Protein required for bipolar budding pattern
434	YHR218W	—	2.37694362	2.4297245	4.1990669	Protein with similarity to other subtelomerically-encoded proteins including YHR219P and YFL065P, probable pseudogene
435	YGL026C	(TRP5)	3.92053304	2.4267316	2.4752996	Tryptophan synthase, last (fifth) step in tryptophan biosynthesis pathway
436	YJL017W	—	2.745014	2.4179146	2.8613495	Protein of unknown function
437	YNL161W	—	4.7525671	2.4161417	2.324762	Serine/threonine protein kinase of unknown function
438	YOR141C	(ARP8)	5.68817037	2.4122798	1.7395537	Protein with similarity to actin and actin-related proteins ARP1P-ARP10P
439	YAL042W	—	2.84377325	2.4057529	3.7961408	Protein of unknown function, has 2 potential transmembrane domains
440	YGR270W	(YTA7)	2.68803581	2.4056715	1.945755	Protein with similarity to members of the AAA family of ATPases
441	YBR119W	(MUD1)	2.83912216	2.4051525	1.3987642	U1 SNRNP A protein (SNRNA-associated protein) with 2 RNA recognition (RRM) domains
442	YDR052C	(DBF4)	6.85835185	2.4036928	1.5834960	Regulatory subunit for CDC7P protein kinase, required for G1/S transition
443	YEL069C	(HXT13)	2.69020108	2.4013304	3.6711431	Protein with strong similarity to hexose transporters, member of the sugar permease family
444	YDR285W	(ZIP1)	8.03633767	2.3921886	0.2216256	Structural protein of the synaptonemal element central element, has predicted coiled-coil domain
445	YJL047C	—	2.8960182	2.3885065	2.0814157	Protein with similarity to clathrin heavy chain in one domain
446	YKL101W	(HSL1)	4.2235071	2.3780286	2.4485279	Serine/threonine protein kinase that interacts genetically with histone mutations
447	YIL143C	(SSL2)	2.16202858	2.3668818	1.9944618	DNA helicase component of RNA polymerase transcription initiation factor TFIIH (factor B)
448	YBR182C	—	3.15043584	2.3653183	2.517131	—
449	YER189W	—	2.65287612	2.3630614	5.1724275	Protein with similarity to subtelomerically-encoded proteins including YIL177P, YHL049P, and YJL225P
450	YLR194C	—	3.11287981	2.3617044	2.923307	Protein of unknown function
451	YGR160W	—	2.13853989	2.3577684	1.8132562	Protein of unknown function
452	YGR258C	(RAD2)	2.06944636	2.3572245	2.1751698	Structure-specific single-stranded DNA endonuclease of the nucleotide excision repairosome
453	YGR162W	(TIF4631)	2.28099935	2.3554791	1.7039222	MRNA CAP-binding protein (EIF4F) 150K subunit
454	YJR036C	—	3.21027204	2.3546452	5.0712893	Possible ubiquitin-protein ligase (E3)
455	YGR124W	(ASN2)	3.37829988	2.3505148	2.4742017	Asparagine synthetase (L-aspartate; L-glutamine amidoligase [AMP-forming]), ASN1P and ASN2P are isozymes
456	YDL180W	—	2.20643197	2.3467843	1.8047293	Protein of unknown function
457	YDR266C	—	3.29383065	2.3411759	2.3118864	Protein of unknown function
458	YAR073W	—	7.67257484	2.3325262	1.6890618	Protein with strong similarity to PUR5P, may be an inosine-5'-monophosphate dehydrogenase
459	YPL048W	(CAM1)	2.18528771	2.3294863	3.3106924	—
460	YEL030W	(ECM10)	1.99868799	2.3236082	2.3835153	Protein possibly involved in cell wall structure or biosynthesis
461	YLL058W	—	6.13836096	2.3223158	2.3541199	Protein with similarity to neurospora crassa O-succinylhomoserine (thiol)-lyase
462	YJR010W	(MET3)	8.36384636	2.3172147	1.5113084	ATP-sulfurylase (sulfate adenyllyltransferase)
463	YER110C	(KAP123)	3.02732098	2.3160572	1.8042941	Karyopherin-beta, involved in nuclear import of ribosomal proteins

TABLE 2*-continued

Seq. Num.	Clone ID	ALIAS	CJ-4hr/ LP-4hr	K-50/CK	K-100/CK	Gene Description
464	YGL063W	(PUS2)	2.17517427	2.3124794	4.1754638	Pseudouridine synthase
465	YPL184C	—	3.3404012	2.3122475	2.2563666	Protein of unknown function
466	YGR254W	(ENO1)	2.05650599	2.3095639	1.9054756	Enolase 1 (2-phosphoglycerate dehydratase), converts 2-phospho-D-glycerate to phosphoenolpyruvate in glycolysis
467	YIL108W	—	3.15926869	2.3086561	2.5782072	Protein of unknown function
468	YDR388W	(RYS167)	2.34115713	2.3058518	2.6912527	Protein with A SH3 domain that affects actin distribution and bipolar budding
469	YNL323W	—	2.29668952	2.3038327	2.0645985	Protein with similarity to YCX1P
470	YBL076C	(ILS1)	2.31635893	2.3036041	1.7634202	Isoleucyl-TRNA synthetase
471	YLR217W	—	2.57939547	2.2859565	1.6611523	Protein of unknown function
472	YGR294W	—	8.48668724	2.2857763	1.7132102	Protein of the PAU1 family
473	YDL070W	—	2.16064033	2.2854538	3.7599153	—
474	YOL044W	—	2.15373467	2.2849315	2.1736446	—
475	YGL145W	(TIP20)	4.18903489	2.2829973	1.6161221	Cytoplasmic protein that interacts physically with SEC20P, required for ER to Golgi transport
476	YLR044C	(PDC1)	2.21772333	2.2774972	1.9431592	Pyruvate decarboxylase isozyme I
477	YNR013C	—	2.0080141	2.2770842	2.4893728	Protein with similarity to PHO87P and YJL198P, member of the phosphate permease family of the major facilitator superfamily (MFS)
478	YML049C	—	2.08547393	2.2761395	2.0329879	—
479	YDR221W	—	2.53153283	2.2731861	1.8131644	Protein with similarity to the beta subunit of human glucosidase II
480	YMR135C	—	4.75727106	2.2636411	4.3609747	Protein of unknown function
481	YKR001C	(YPS1)	2.48277065	2.2630712	1.5678763	Vacuolar sorting protein, member of the dynamin family of GTPases
482	YLR413W	—	2.80009402	2.2629262	2.3695083	Protein of unknown function
483	YDR122W	(KIN1)	2.0434064	2.2623436	2.3432635	Serine/threonine protein kinase, related to KIN2P and <i>S. pombe</i> KIN1
484	YIL154C	(IMP2)	2.216207	2.2548739	2.2466776	—
485	YKL068W	(NUP100)	2.2598003	2.2529093	2.7012733	Nuclear pore protein (nucleoporin) of the GLFG family, may be involved in binding and translation of proteins during nucleocytoplasmic transport
486	YHR190W	(ERG9)	2.81318531	2.2475123	1.7238705	Squalene synthesis (farnesyl-diphosphate farnesyltransferase), acts as a branch point in the isoprenoid biosynthesis pathway
487	YGL179C	—	4.83814707	2.2398396	3.8786749	Serine/threonine protein kinase with similarity to ELM1P and KIN82P
488	YOL017W	—	3.01741322	2.2303862	2.2459064	Protein of unknown function
489	YHR189W	—	2.0021212	2.22911	2.2289936	Putative peptidyl-TRNA hydrolase (PTH)
490	YNL208W	—	3.64860898	2.2181817	2.5247363	Protein of unknown function
491	YHR04LC	(SRB2)	2.27216109	2.2178582	2.4847273	Component of the RNA polymerase II holoenzyme and Kornberg's mediator (SRB) subcomplex
492	YPR080W	(TEF1)	2.50402057	2.2115095	1.8587879	Translation elongation factor EF-1alpha (TEF1 TEF2 code for identical proteins)
493	YBR229C	(ROT2)	2.45186053	2.2034499	2.1844611	Catalytic (alpha) subunit of glucosidase II
494	YGR262C	—	2.83275613	2.2029336	1.9251756	Protein with similarity to apple tree calcium/calmodulin-binding protein kinase PIR:JQ2251
495	YER144C	(UBP5)	3.38126089	2.1994294	2.7106303	Ubiquitin-specific protease (ubiquitin C-terminal hydrolase), homologous to DOA4P and human TRE-2
496	YDR264C	(AKR1)	3.13151279	2.1983967	2.7516536	Ankyrin repeat-containing protein that has an inhibitory effect on signaling in the pheromone pathway
497	YLR427W	—	2.2498541	2.1938243	2.5059695	Protein of unknown function
498	YLR374C	—	2.26923061	2.1927227	2.6395044	Protein of unknown function
499	YMR092C	(AIP1)	2.2241966	2.1917074	2.1939749	Actin interacting protein, has 4 WD (WD-40) repeats
500	YDR294C	—	2.20085342	2.1899557	2.3333139	—
501	YMR296C	(LCB1)	2.1334221	2.1891645	1.9030014	Component of serin C-palmitoyltransferase, first step in biosynthesis of long-chain base component of sphingolipids
502	YKR039W	(GAP1)	1.99105648	2.1881751	1.2556866	General amino acid permease, proton symport transporter for all naturally-occurring L-amino acids, 4-aminobutyric acid (GABA), ornithine, citrulline, some D-amino acids, and some toxic analogs
503	YDR422C	(SIP1)	2.62373247	2.1870761	2.0836347	Multicopy suppressor of SNF1, related to GAL83P/SPM1P and SPM2P

TABLE 2*-continued

Seq. Num.	Clone ID	ALIAS	CJ-4hr/ LP-4hr	K-50/CK	K-100/CK	Gene Description	
504	YMR080C	(NAM7)	2.82340116	2.1828046	2.1714828	Protein involved with NMD2P and UPF3P in decay of mRNA containing nonsense codons	
505	YBL106C	—	2.38138747	2.1809814	2.7798326	—	
506	YEL043W	—	3.44125375	2.1784956	2.8076042	Protein of unknown function	
507	YBR222C	(FAT2)	5.13679804	2.1781103	3.0936394	Peroxisomal AMP-binding protein	
508	YDR004W	(RAD57)	2.26389978	2.1754266	2.076582	Component of recombinosome complex involved in meiotic recombination and recombinational repair, with RAD55P promotes DNA strand exchange by RAD51P recombinase	
509	YHR174W	(ENO2)	2.38714668	2.1702816	1.9697417	Enolase 2(2-phosphoglycerate dehydratase), converts 2-phospho-D-glycerate to phosphoenolpyruvate in glycolysis	
510	YER043C	(SAH1)	3.73200717	2.1669937	1.6246235	Adenosylhomocysteinase (S-adenosylhomocysteine hydrolase)	
511	YKR012C	—	2.41358469	2.1555775	1.1414615	Protein of unknown function	
512	YOL007C	—	3.17872347	2.1529948	1.2712945	—	
513	YMR220W	(ERG8)	2.68816133	2.1489328	2.0693924	Phosphomevalonate kinase, converts mevalonate-5-phosphate to mevalonate pyrophosphate, involved in isoprene and ergosterol biosynthesis pathways	
514	YDR062W	(LCB2)	2.54448949	2.1430094	1.9627647	Subunit of serine C-palmitoyltransferase, first step in sphingolipic biosynthesis, and suppressor of calcium-sensitivity of CSG2	
515	YAL048C	—	5.02313141	2.1384748	4.221132	Protein with weak similarity to RAS1P, RAS2P, and other GTP-binding proteins of the RAS superfamily	
516	YBL111C	—	2.17340644	2.1313903	3.8030907	—	
517	YJL108C	—	4.56646166	2.1302533	2.8609713	Protein of unknown function, contains 8 potential transmembrane domains	
518	YJL141C	(YAK1)	2.80000608	2.1277388	2.8291776	Serine/threonine protein kinase, negative regulator of cell growth acting in opposition to CAMP-dependent protein kinase A	
519	YJL102W	(MEF2)	2.08592026	2.1220696	1.6098307	Mitochondrial translation elongation factor, promotes GTP-dependent translocation of nascent chain from A-site to P-site of ribosome	
520	YDL174C	(DLD1)	2.28050309	2.1220649	2.4305801	D-lactate dehydrogenase (cytochrome), (D-lactate ferricytochrome C oxidoreductase) (D-LCR), mitochondrial	
521	YMR011W	(HXT2)	7.25080973	2.1188378	1.6420019	High-affinity hexose transporter, member of sugar permease family	
522	YLR129W	(DIP2)	3.36115373	2.1126408	2.0325416	DOM34P-interacting protein, has WD (WD-40) repeats	
523	YML008C	(ERG6)	2.51872662	2.1091692	1.7889829	S-adenosylmethionine delta-24-sterol-C-methyltransferase, carries out methylation of zymosterol as part of the ergosterol biosynthesis pathway	
524	YGL245W	—	2.30162026	2.1065078	1.4267053	Glutamyl-TRNA synthetase, member of the Class I aminoacyl TRNA synthetase family	
525	YGL024W	—	2.67631735	2.1046757	1.4610387	Protein of unknown function	
526	YHL027W	(RIM101)	2.57210755	2.1033157	2.5927892	Zinc-finger protein involved in induction of IME1	
527	YGR281W	(YOR1)	4.18259907	2.0935061	2.3634092	Oligomycin-resistance factor, member of the ATP-binding cassette (ABC) superfamily	
528	YIL175W	—	2.10803474	2.0859355	2.4771166	—	
529	YHL019C	(APM2)	1.9956708	2.0845729	3.0618718	Clathrin-associated protein (AP) complex, medium subunit	
530	YAL019W	(FUN30)	5.19927199	2.0806959	1.7340212	—	
531	YGL112C	(TAF60)	2.21463331	2.0765265	2.1891308	Component of TAF(II) complex (TBP-associated protein complex) required for activated transcription by RNA polymerase II	
532	YNL218W	—	2.28887465	2.0761	1.6749939	Protein with similarity to <i>E. coli</i> DNA polymerase III gamma and TAU subunits	
533	YML058C-A	—		217.969407	2.0723568	3.2869214	
534	YOL156W	(HXT11)	5.12784966	2.0709411	2.2192118	Low-affinity glucose permease	
535	YGR218W	(CRM1)	2.32581989	2.0675233	1.5505702	Exportin, beta-karyopherin	
536	YGR296W	—	3.15948331	2.0664535	3.7402619	Protein with similarity to other subtelomerically-encoded proteins including YER190P (YPL283 and YGR296W code for identical proteins)	
537	YLR176C	—	2.54329087	2.0627475	1.4892288	—	
538	YDL229W	(SSB1)	5.21935107	2.0615889	2.0067653	Heat shock protein of HSP70 family involved in the translational apparatus	

TABLE 2*-continued

Seq. Num.	Clone ID	ALIAS	CJ-4hr/ LP-4hr	K-50/CK	K-100/CK	Gene Description
539	YER034W	—	2.57654853	2.0562947	1.9025056	Protein of unknown function
540	YKR050W	(TRK2)	2.23638067	2.056259	4.703529	Potassium transporter of the plasma membrane, moderate affinity, member of the potassium permease family of the major facilitator superfamily
541	YIL113W	—	7.07756282	2.0539759	2.28618	Dual-specificity protein phosphatase
542	YCR023C	—	2.01851078	2.0520751	2.2109695	Member of major facilitator superfamily (MFS) multidrug-resistance protein family 2
543	YMR069W	—	4.45745957	2.0520592	0	Protein of unknown function
544	YAL020C	(ATS1)	3.02597511	2.050802	2.0781706	Protein with similarity to human RCC1 protein, suppressor of mutations in alpha tubulin
545	YNL256W	—	3.16308725	2.045577	1.8697374	Protein with similarity to bacterial dihydropteroate synthase
546	YMR124W	—	2.65610298	2.0431312	2.2988806	Protein of unknown function, has potential coiled-coil region (GB:Z49273)
547	YOR162C	—	2.4478098	2.0361958	2.1075035	—
548	YOR353C	—	2.20965265	2.0220258	1.7471747	Protein with weak similarity to adenylate cyclases
549	YPL028W	(ERG10)	2.86559138	2.0185951	1.6989337	Acetyl-CoA acetyltransferase (acetoacetyl-CoA thiolase), first step in mavalonate/sterol pathway
550	YIL114C	(POR2)	2.24322702	2.0152799	2.367678	Outer mitochondrial membrane porin (voltage-dependent anion-selective channel)
551	YDL029W	(ACT2)	2.07186888	2.0140172	1.810394	—
552	YDL143W	(CCT4)	2.3041307	2.0128325	1.6478427	Component of chaperonin-containing T-complex (TCP ring complex, TRIC), homologous to mouse CCT4
553	YPL267W	—	2.06501413	2.0119076	1.6761922	Protein of unknown function
554	YOL105C	—	2.79225712	2.0026061	2.23737	—
555	YML004C	(GLO1)	2.19630894	2.0015677	1.7985136	Glyoxalase I, converts methylglyoxal and glutathione into S-D-lactoylglutathione
556	YMR266W	—	2.47393267	1.991188	1.727182	Protein of unknown function, probable integral membrane glycoprotein
557	YPL194W	—	2.87006368	0.4961465	1.5346869	—
558	YOR152C	—	2.74047761	0.4915256	0.2221023	Protein of unknown function
559	YDR242W	(AMD2)	8.28951711	0.4819032	0.9215489	Protein with similarity to amidases
560	YFL054C	—	7.43223753	0.4793582	0.6136582	Protein with similarity to FPS1P and YPR192P, member of MIP family of transmembrane channels
561	YAR068W	—	3.24259317	0.479021	1.2297001	Protein with similarity to ICWP protein
562	YAL001C	(TFC3)	2.94740587	0.4742746	1.1915566	RNA polymerase transcription initiation factor TFIIC (TAU), 138 KDA subunit
563	YLR454W	—	5.72921213	0.4716283	1.641906	Protein of unknown function
564	YDL020C	(SON1)	2.27378766	0.4591519	0.8208918	—
565	YMR225C	(MRPL44)	0.19372389	0.4430311	0.4019617	Mitochondrial ribosomal protein of the large subunit (YMR44)
566	YJR038C	—	9.06373624	0.4422872	4.1801655	Protein of unknown function
567	YDR380W	—	0.1136124	0.4417559	0.8241167	Protein with similarity to pyruvate decarboxylase, pyruvate oxidase, acetolactate synthase (large subunit), and other enzymes that require thiamine pyrophosphate
568	YKL170W	(MRPL38)	0.20347891	0.4296401	0.4533368	Mitochondrial ribosomal protein of the large subunit (YML38) (<i>E. coli</i> L14), belongs to the L14 family of prokaryotic ribosomal proteins
569	YGR248W	(SOL4)	0.17664863	0.4293198	0.4062793	Protein of unknown function
570	YER058W	(PET117)	0.18996331	0.4289442	0.4202828	Protein involved in assembly of cytochrome oxidase
571	YBR039W	(AIP3)	0.18787084	0.4197886	0.2837245	F1-gamma AIP synthase
572	YDL102W	(CDC2)	17.5853214	0.4169873	0.0258767	—
573	YJR153W	—	3.65551445	0.4116558	0.6086987	—
574	YMR188C	—	0.20743995	0.4113817	0.3381207	Protein with similarity to 30S ribosomal proteins (S17)
575	YBR244W	—	0.16093632	0.4035137	0.3438917	Protein with similarity to glutathione peroxidase
576	YDR523C	(SPS1)	10.8815611	0.4014712	0.3371725	Serine/threonine protein kinase involved in middle/late stage of meiosis
577	YDL031W	—	2.0561223	0.3989968	0.6791327	Protein with similarity of RNA helicases of dead/DEAH box family
578	YER109C	(FLO8B)	2.33584341	0.3826502	2.0529509	—
579	YIR017C	(MET28)	2.97658904	0.3775372	0.3008895	Transcriptional activator of the basic leucine zipper (BZIP) family, works with MET4P and CBF1P to regulation sulfur amino acid metabolism

TABLE 2*-continued

Seq. Num. Clone ID	ALIAS	CJ-4hr/ LP-4hr	K-50/CK	K-100/CK	Gene Description
580 YDL016C	—	3.9417341	0.374232	0.2672688	Protein of unknown function
581 YIR028W	(DAL4)	2.5006493	0.3741716	3.0010653	Allantoin permease, member of the uracil/allantoin permease family of the major facilitator superfamily (MFS)
582 YOR124C	(UBP2)	2.8382974	0.3622925	0.3859773	Ubiquitin-specific protease (ubiquitin C-terminal hydrolase), cleaves at the C-terminus of ubiquitin
583 YBL108W	—	0.1900473	0.3575329	0.5467376	Protein of unknown function
584 YDR259C	—	5.62713626	0.3429355	0.2335082	—
585 YDR253C	(MET32)	2.86314943	0.3397175	0.3279043	Zinc-finger protein involved in transcriptional regulation of methionine metabolism
586 YJL196C	(ELO1)	0.17135352	0.3378086	0.3752547	Fatty acid elongation protein involved in elongation of tetradecanoic acid to hexadecanoic acid
587 YDR141C	—	0.09160554	0.3290633	0.1693929	Protein of unknown function, member of the major facilitator superfamily (MFS)
588 YBR069C	(VAP1)	3.0181038	0.3157547	1.2268269	Amino acid permease for valine, leucine, isoleucine, tyrosine, and tryptophan
589 YOR314W	—	2.65430513	0.2917342	0.3312621	Protein of unknown function
590 YDL068W	—	0.11556176	0.2684108	0.1521109	Protein of unknown function
591 YPL136W	—	2.17418921	0.2530647	3.1708409	Protein of unknown function
592 YGL034C	—	0.1411795	0.2524039	0.3723439	Protein of unknown function
593 YLR162W	—	4.13626663	0.2515583	0.6851592	Protein of unknown function
594 YMR193C-A	—	3.34099753	0.2354896	0.3596816	—
595 YMR146C	(TIF34)	5.0351989	0.2248204	0.7193538	Translation initiation factor EIF3, P39 subunit, has 2 WD (WD-40) repeats
596 YFL012W	—	71.9436495	0.2235373	1.5215902	Protein of unknown function
597 YER096W	—	7.21258235	0.1766673	0.4170679	—
598 YNR071C	—	2.01488788	0.1446196	0.0535063	Protein with similarity to UDPglucose 4-epimerase
599 YLR419W	—	0.20769335	0.1102431	0.9141258	Protein with similarity to several pre-mRNA splicing factors
600 YKL105C	—	3.23146223	0.086572	5.0836556	Protein of unknown function
601 YLR142W	(PUT1)	2.2907881	0.0854218	0.6671487	Proline oxidase, first step in synthesis of glutamate from proline
602 YDL239C	—	7.81000565	0.0417738	0.347901	Protein of unknown function
603 YHR137W	(ARO9)	0.07724918	0.0347684	0.0703134	Aromatic amino acid aminotransferase II
604 YDR374C	—	17.25276	0	4.6059679	Protein of unknown function
605 YIL100W	—	9.97598883	0	2.8122773	Protein of unknown function, questionable ORF
606 YPL025C	—	9.52247441	0	20.22382	Protein of unknown function
607 YOR072W	—	7.48662389	0	6.2287404	Protein of unknown function
608 YNL242W	—	6.47720448	0	2.5753253	Protein of unknown function
609 YIR027C	(DAL1)	5.64113227	0	0	Allantoinase, first step in the degradation of allantoin as a secondary nitrogen source
610 YOR139C	—	5.46648132	0	11.760995	Transcription factor with domains homologous to MYC oncoprotein and yeast HSF1P, required for normal cell surface assembly and flocculence
611 YEL019C	(MMS21)	3.34008483	0	2.069236	Protein of unknown function
612 YDL132W	(cdc53)	3.16426832	0	0.1467847	—
613 YOR177C	—	2.97842594	0	0.435871	Protein of unknown function
614 YML042W	(CAT2)	2.76437696	0	16.65885	Carnitine O-acetyltransferase, peroxisomal and mitochondrial
615 YER044C-A	(MEI4)	2.5971776	0	0	Protein required early in meiosis for meiotic recombination, chromosome synapsis, and viable spore formation
616 YGR083C	(GCD2)	2.32134339	0	0	Translation initiation factor EIF2B (guanine nucleotide exchange factor), 71 KDA (delta) subunit
617 YAR030C	—	2.06301879	0	0	Protein of unknown function, probable non-coding ORF

TABLE 2*-continued

Seq. Num.	Clone ID	ALIAS	CJ-4hr/ LP-4hr	K-50/CK	K-100/CK	Gene Description
618	YJR157W	—	0.2073771	0	0.6711879	Protein of unknown function
619	YHR217C	—	0.2061042	0	0.549346	Protein of unknown function
620	YKL100C	—	0.12715731	0	40.399169	Protein of unknown function

*Table Headings:

Clone ID: A clone ID designation number.

Alias: Alternative gene names used in the literature. This information is provided by YPD™, Hodges et al. Nucl. Acids Res. 27: 69-73 (1999), the entirety of which is herein incorporated by reference.

CJ-4hr/LP-4hr: Expression level in the mutant CJ517 as compared with the respective wild type strain LPY9 at 4hr sampling of log phase growth of yeast (ratio of mutant expression level/control expression level). CJ refers to the mutant CJ517 (The mutant is defective in the gene (ERG11) codes for C14 demethylase enzyme in the sterol biosynthetic pathway). LP refers to the respective wild type strain LPY9, used to compare the gene expression profile with the mutant.

K-50/CK: Expression level in the wild type yeast LPY9, at 2 hr after treatment with 50 micro gram/ml ketoconazole as compared to the wild type LPY9 strain without ketoconazole treatment (ratio of treatment expression level/control expression level). K refers to ketoconazole treatment. The clones listed in Table 2 are either up or down regulated in the mutant (CJ517) as well as in response to ketoconazole treatment.

K-100/CK: Expression level in the wild type yeast LPY9, at 2 hr after treatment with 100 micro gram/ml ketoconazole as compared to the wild type LPY9 strain without ketoconazole treatment (ratio of treatment expression level/control expression level).

Gene Description: Description of the clone listed in column 1.

Table 3, below, lists the RNAs from Table 2 that correspond to genes or structural regions implicated in transcription regulation.

TABLE 3*

Seq. Num.	Clone ID	ALIAS	CJ-4 hr/ LP-4 hr	K-50/CK	K-100/CK	Gene Description
30	YOR237W	(HES1)	134.648161	1417.62621	1358.12348	Protein implicated in ergosterol biosynthesis, member of the KES1/HES1/OSH1/YKR003W family of oxysterol-binding (OSBP) proteins
42	YDR213W	—	18.2079478	32.1360646	58.3586116	Protein with similarity to transcription factors, has ZN[2]-CYS[6] fungal-type binuclear cluster domain in the N-terminal region
74	YGR177C	(ATF2)	3.7081426	11.830167	12.5552685	Alcohol O-acetyltransferase
75	YFR034C	(PHO4)	14.8112083	11.2160731	20.8445145	Basic helix-loop-helix (BHLH) transcription factor required for expression of phosphate pathway, hyperphosphorylation by PHO80P-PHO85P cyclin-dependent protein kinase complex causes inactivation
83	YOL067C	(RTG1)	30.4142081	10.0270648	27.3663295	Basic helix-loop-helix (BHLH) transcription factor involved in inter-organelle communication between mitochondria, peroxisomes, and nucleus
100	YJL127C	(SPT10)	4.01528284	7.83944269	10.0960266	Protein that amplifies the magnitude of transcriptional regulation at various loci
111	YMR037C	(MSN2)	6.80686734	6.42359685	7.66129891	Zinc-finger transcriptional activator for genes involved in the multistress response and genes regulated through SNF1P
118	YCR048W	(ARE1)	9.11370518	6.1039374	10.5312906	Acyl-CoA:sterol acyltransferase (sterol-ester synthetase)
131	YAL013W	(DEP1)	8.79366086	5.54633863	6.42500999	Regulator of phospholipid metabolism
132	YIL084C	(SDS3)	1.99582364	5.54306878	6.90742248	Suppressor of silencing defect
157	YKR034W	(DAL80)	3.91750209	5.0436172	7.28385659	GATA-type zinc finger transcriptional repressor for allantoin and 4-aminobutyric acid (GABA) catabolic genes
172	YLR098C	(CHA4)	2.05280928	4.75643469	5.58664651	Zinc-finger protein required for activation of CHA1, has A ZN[2]-CYS[6] fungal-type binuclear cluster domain
180	YDR389W	(SAC7)	3.89197011	4.56095992	4.31431086	GTPase-activating protein for RHO1P

TABLE 3*-continued

Seq. Num.	Clone ID	ALIAS	CJ-4 hr/ LP-4 hr	K-50/CK	K-100/CK	Gene Description
202	YDL088C	(ASM4)	4.39685251	4.17572645	3.32103404	Suppressor of temperature-sensitive mutations in POL3P (DNA polymerase delta)
206	YBL005W	(PDR3)	3.75060207	4.14490535	6.08273054	Transcription factor related to PDR1P, contains A ZN[2]-CYS[6] fungal-type binuclear cluster domain in the N-terminal region
242	YGL071W	(RCS1)	3.39203358	3.69630773	4.53101664	Regulatory protein involved in iron uptake
255	YAR044W	(OSH1)	4.12112011	3.624939	3.88396219	Protein implicated in ergosterol biosynthesis, member of the KES1/HES1/OSH1/YKR003W family of oxysterol-binding (OSBP) proteins
256	YLR120C	(YAP3)	6.14265883	3.62298451	4.42985615	Transcription factor of the basic leucine zipper (BZIP) family, one of eight members of a novel fungal-specific family of BZIP proteins
260	YJR017C	(ESS1)	2.98118086	3.55874146	3.22082555	Processing/termination factor, involved in transcription termination or 3'-end processing of pre-mRNA
271	YMR019W	(STB4)	3.2576922	3.44146214	3.39764598	SIN3P-binding protein, has ZN[2]-CYS[6] fungal-type binuclear cluster domain in the N-terminal region
278	YLR153C	(ACS2)	3.45528019	3.37854457	3.12858117	Acetyl-CoA synthetase (acetate-CoA ligase)
289	YPL119C	(DBP1)	5.87199247	3.24642228	2.19736599	ATP-dependent RNA helicase of dead box family, suppressor of SPP81/DED1
290	YGL014W	—	3.11296478	3.22942947	3.6382821	Protein with pumilio repeats that is involved with MPT5P in relocalization of SIR3P and SIR4P from telomeres to the nucleolus
296	YGL192W	(IME4)	2.89030953	3.17038103	6.47841053	Positive transcription factor for IME1 and IME2, mediates control of meiosis by carrying signals regarding mating type (A/alpha) and nutritional status
297	YMR047C	(NUP116)	2.56622055	3.17022339	4.77420515	Nuclear pore protein (nucleoporin) of the GLFG family, may be involved in binding and translocation of nuclear proteins
301	YLR249W	(YEF3)	3.59397167	3.14453335	2.63195398	Translation elongation factor EF-3A, member of ATP-binding cassette (ABC) superfamily
322	YOR337W	(TEA1)	2.13152473	2.97907151	4.82285812	TY1 enhancer activator of the GAL4P-type family of DNA-binding proteins
331	YCR084C	(TUP1)	2.40138822	2.92198431	3.27182635	General repressor of transcription (with SSN6P), member of WD (WD-40) repeat family
336	YPL226W	—	2.45263084	2.88856775	2.55579443	Protein with similarity to members of the ATP-binding cassette (ABC) superfamily
345	YJR019C	(TES1)	4.07777555	2.83032346	2.07248965	Acyl-CoA thioesterase
346	YBL008W	(HIR1)	7.24580603	2.82847131	2.88668127	Histone transcription inhibitor, required for periodic repression of 3 of the 4 histone gene loci and for autogenous repression of HTA1-HTB1 locus by H2A and H2B
349	YGL001C	—	3.91981575	2.82148161	1.98527852	Protein with similarity to nocardia SP, cholesterol dehydrogenase
359	YCL037C	(SRO9)	8.35007693	2.78557477	2.39358801	Suppressor of YPT6 null and RHO3 mutations
367	YDR088C	(SLU7)	2.07293165	2.73396273	2.68767436	Pre-mRNA splicing factor affecting 3' splice site choice, required only for the second catalytic step of splicing
376	YBR289W	(SNF5)	2.00671327	2.68812945	3.03861899	Component of SW1/SNF global transcription activator complex, acts to assist gene-specific activators through chromatin remodeling

TABLE 3*-continued

Seq. Num.	Clone ID	ALIAS	CJ-4 hr/ LP-4 hr	K-50/CK	K-100/CK	Gene Description
400	YPL237W	(SUI3)	2.5966981	2.5628077	2.54794558	Translation initiation factor EIF2beta subunit
406	YOR127W	(RGA1)	3.85804733	2.53166489	2.56973414	RHO-type GTPase-activating protein (GAP) for CDC42P
416	YFR009W	(GCN20)	2.63782118	2.48595438	2.16133777	Component of a protein complex required for activation of GCN2P protein kinase in response to amino acid starvation, member of ATP-binding cassette (ABC) superfamily
417	YDR211W	(GCD6)	2.22567451	2.48354852	1.82406386	Translation initiation factor EIF2B (guanine nucleotide exchange factor), 81 KDA (beta) subunit
440	YGR270W	(YTA7)	2.68803581	2.4056715	1.94575504	Protein with similarity to members of the AAA family of ATPases
441	YBR119W	(MUD1)	2.83912216	2.40515252	1.39876418	U1 SNRNP A protein (SNRNA-associated protein) with 2 RNA recognition (RRM) domains
442	YDR052C	(DBF4)	6.85835185	2.40369283	1.58349756	Regulatory subunit for CDC7P protein kinase, required for G1/S transition
492	YPR080W	(TEF1)	2.50402057	2.21150946	1.85878786	Translation elongation factor EF-1alpha (TEF1 and TEF2 code for identical proteins)
496	YDR264C	(AKR1)	3.13151279	2.19839665	2.75165355	Ankyrin repeat-containing protein that has an inhibitory effect on signaling in the pheromone pathway
503	YDR422C	(SIP1)	2.62373247	2.18707608	2.08363472	Multicopy suppressor of SNF1, related to GAL83P/SPM1P and SPM2P
504	YMR080C	(NAM7)	2.82340116	2.1825046	2.17148277	Protein involved with NMD2P and UPF3P in decay of MRNA containing nonsense codons
515	YAL048C	—	5.02313141	2.13847476	4.22113197	Protein with weak similarity to RAS1P, RAS2P, and other GTP binding proteins of the RAS superfamily
526	YHL027W	(RIM101)	2.57210755	2.10331571	2.59278915	Zinc-finger protein involved in induction of IME1
531	YGL112C	(TAF60)	2.21463331	2.07652653	2.18913076	Component of TAF(II) complex (TBP-associated protein complex) required for activated transcription by RNA polymerase II
549	YPL028W	(ERG10)	2.86559138	2.01859514	1.69893374	Acetyl-CoA acetyltransferase (acetoacetyl-CoA thiolase), first step in mevalonate/sterol pathway
621	YNR019W	(ARE2)	2.1	1.79103463	2.85442	Acyl-CoA:sterol acyltransferase (sterol-ester synthetase)
560	YFL054C	—	7.43223753	0.47935821	0.61365816	Protein with similarity to FPS1P and YPR192P, member of MIP family of transmembrane channels
562	YAL001C	(TFC3)	2.94740587	0.47427458	1.19155655	RNA polymerase transcription initiation factor TFIIC (TAU), 138 KDA subunit
579	YIR017C	(MET28)	2.97658904	0.3775372	0.30088953	Transcriptional activator of the basic leucine zipper (BZIP) family, works with MET4P and CBF1P to regulation sulfur amino acid metabolism
585	YDR253C	(MET32)	2.86314943	0.33971751	0.32790428	Zinc-finger protein involved in transcriptional regulation of methionine metabolism
595	YMR146C	(TIF34)	5.0351989	0.22482039	0.71935381	Translation initiation factor EIF3, P39 subunit, has 2 WD (WD-40) repeats
616	YGR083C	(GCD2)	2.32134339	0	0	Translation initiation factor EIF2B (guanine nucleotide exchange factor), 71 KDA (delta) subunit

TABLE 3*-continued

Seq. Num. Clone ID	ALIAS	CJ-4 hr/ LP-4 hr	K-50/CK	K-100/CK	Gene Description
610 YOR139C	(SFL1)	5.46648132	0	11.7609951	Transcription factor with domains homologous to MYC oncoprotein and yeast HSF1P, required for normal cell surface assembly and flocculence

*Table Headings:

Clone ID: A clone ID designation number.

CJ-4 hr/LP-4 hr: Expression level in the mutant CJ517 as compared with the respective wild type strain LPY9 at 4 hr sampling of log phase growth of yeast (ratio of mutant expression level/control expression level). Genes in the Table are either up or down regulated in the mutant (CJ517) as well as in response to ketoconazole treatment.

K-50/CK: Expression level in the wild type yeast LPY9, at 2 hr after treatment with 50 micro gram/ml ketoconazole as compared to the wild type LPY9 strain without ketoconazole treatment (ratio of treatment expression level/control expression level).

K-100/CK: Expression level in the wild type yeast LPY9, at 2 hr after treatment with 100 micro gram/ml ketoconazole as compared to the wild type LPY9 strain without ketoconazole treatment (ratio of treatment expression level/control expression level).

Gene Description: Description of the clone listed in column 1.

In addition, for example, Table 2 identifies a yeast HES1 gene as a gene with an associated change in mRNA levels in the two different comparisons. Fang et al. *EMBO J* 15:6447-59 (1996), the entirety of which is herein incorporated by reference, reported a mutation in HES1, which caused a 55% reduction in carbon flux through the mevalonate pathway in yeast.

Each of the sequences listed in Table 2 or 3 represents a gene that effects sterol levels, directly or indirectly, or whose expression changes as a result of alterations in the sterol synthesis pathway.

EXAMPLE 2

Sequences that encode for the yeast HES1 protein are used to search databases for homologues from other species. A number of different databases can be used for these searches, including, for example, dbEST, GenBank, EMBL, SwissProt, PIR, and GENES. In addition, various algorithms for searching can be selected, such as, for example, the BLAST suite of programs at the default values. Typically, matches found with BLAST P values equal or less than 0.001 (probability) or BLAST Score of equal or greater than 90 are classified as hits. If the program used to determine the hit is HMMSW then the score refers to HMMSW score. The GenBank database is searched with BLASTN and BLASTX (default values). Sequences that pass the hit probability threshold of $10c^{-8}$ are considered hits.

TABLE 4

Seq. Num. Clone ID	Sequence: DNA/Protein	Hit description	Library
1 701100307CPR9855	DNA	Yeast HES 1 homolog	SOYMON028
2 701001443CPR9857	DNA	Yeast HES 1 homolog	SOYMON018
3 701010572CPR9854	DNA	Yeast HES 1 homolog	SOYMON019
4 701176735CPR9736	DNA	Yeast HES 1 homolog	SATMONN05
5 Z75145	DNA	Protein implicated in ergosterol biosynthesis, member of the KES1/HES1/OSH1/YKR003W family of oxysterol-binding (OSBP) proteins	—
622 701100307CPR9855	Protein	Yeast HES 1 homolog	SOYMON028
623 701001443CPR9857	Protein	Yeast HES 1 homolog	SOYMON018
624 701010572CPR9854	Protein	Yeast HES 1 homolog	SOYMON019
625 701176735CPR9736	Protein	Yeast HES 1 homolog	SATMONN05
626 Z75145	Protein	Protein implicated in ergosterol biosynthesis, member of the KES1/HES1/OSH1/YKR003W family of oxysterol-binding (OSBP) proteins	—
6 701003888H1	DNA	Yeast HES 1 homolog	SOYMON019
7 701001351H1	DNA	Yeast HES 1 homolog	SOYMON018
8 700672545H1	DNA	Yeast HES 1 homolog	SOYMON006
9 700664054H1	DNA	Yeast HES 1 homolog	SOYMON005
10 700665644H1	DNA	Yeast HES 1 homolog	SOYMON005
11 700764248H1	DNA	Yeast HES 1 homolog	SOYMON020
12 700851444H1	DNA	Yeast HES 1 homolog	SOYMON023
13 700971910H1	DNA	Yeast HES 1 homolog	SOYMON005
14 700652932H1	DNA	Yeast HES 1 homolog	SOYMON003
15 700982894H1	DNA	Yeast HES 1 homolog	SOYMON009
16 701120140H1	DNA	Yeast HES 1 homolog	SOYMON037
17 701064234H1	DNA	Yeast HES 1 homolog	SOYMON034
18 700954013H1	DNA	Yeast HES 1 homolog	SOYMON022
19 701129375H1	DNA	Yeast HES 1 homolog	SOYMON037
20 701043941H1	DNA	Yeast HES 1 homolog	SOYMON032
21 LIB24-114-Q1-E1-H8	DNA	Arabidopsis HES 1 homolog	LIB24
22 LIB22-016-Q1-E1-F3	DNA	Arabidopsis HES 1 homolog	LIB22
23 LIB25-101-Q1-E1-F1	DNA	Arabidopsis HES 1 homolog	LIB25

TABLE 4-continued

Seq. Num. Clone ID	Sequence:		Library
	DNA/Protein	Hit description	
24 AA042357	DNA	Arabidopsis HES 1 homolog	—
25 AA720163	DNA	Arabidopsis HES 1 homolog	—
26 Z29936	DNA	Arabidopsis HES 1 homolog	—
27 T76850	DNA	Arabidopsis HES 1 homolog	—
28 T76580	DNA	Arabidopsis HES 1 homolog	—
29 AA586043	DNA	Arabidopsis HES 1 homolog	—

Homologues to yeast HES1 are also identified in the following libraries: SOYMON003, SOYMON005, SOYMON006, SOYMON009, SOYMON018, SOYMON019, SOYMON020, SOYMON022, SOYMON028, SOYMON023, SOYMON032, SOYMON034, SOYMON027, SATMONN05, LIB22, LIB 24, and LIB 25. These libraries are prepared as follows:

The SATMONN05 cDNA library is a normalized library generated from maize (B73 x Mo17, Illinois Foundation Seeds, Champaign Ill., U.S.A.) root tissue at the V6 development stage. Seeds are planted at a depth of approximately 3 cm into 2–3 inch peat pots containing Metro 200 growing medium. After 2–3 weeks growth they are transplanted into 10 inch pots containing the same growing medium. Plants are watered daily before transplantation and three times a week after transplantation. Peters 15-16-17 fertilizer is applied three times per week after transplanting at a strength of 150 ppm N. Two to three times during the lifetime of the plant, from transplanting to flowering, a total of 900 mg Fe is added to each pot. Maize plants are grown in a greenhouse in 15 hr day/9 hr night cycles. The daytime temperature is approximately 80° F. and the nighttime temperature is approximately 70° F. Supplemental lighting is provided by 1000 W sodium vapor lamps. Tissue is collected when the maize plant is at the 6-leaf development stage. The root system is cut from the mature maize plant and washed with water to free it from the soil. The tissue is immediately frozen in liquid nitrogen and the harvested tissue is then stored at –80° C. until RNA preparation. The RNA is purified from the stored tissue. The library is normalized in two rounds using conditions adapted from Soares et al., *Proc. Natl. Acad. Sci. (U.S.A.)* 91:9928 (1994), the entirety of which is herein incorporated by reference and Bonaldo et al., *Genome Res.* 6: 791 (1996), the entirety of which is herein incorporated by reference except that a significantly longer (48-hours/round) reannealing hybridization was used. SATMON003 is a root tissue library from the same donor.

The SOYMON003 cDNA library is generated from soybean cultivar Asgrow 3244 (Asgrow Seed Company, Des Moines, Iowa U.S.A.) hypocotyl axis tissue from seedlings 2 day after-imbibition. Seeds are planted at a depth of approximately 2 cm into 2–3 inch peat pots containing Metromix 350 medium. Trays are placed in an environmental chamber and grown at 12 hr daytime/12 hr nighttime cycles. The daytime temperature is approximately 29° C. and the nighttime temperature approximately 24° C. Soil is checked and watered daily to maintain even moisture conditions. Tissue is collected 2 days after the start of imbibition. The 2 days after imbibition samples are separated into 3 collections after removal of an adhering seed coat. At 2 days after imbibition under the above conditions, the seedlings have significant expansion of the axis and are close to emerging from the soil. A few seedlings have cracked the soil surface and exhibited slight greening of the exposed cotyledons. The seedlings are washed in water to remove soil, hypocotyl axis harvested and immediately frozen in liquid nitrogen. The harvested tissue is then stored at –80°

C. until RNA preparation. The RNA is purified from the stored tissue and the cDNA library is constructed.

The stored RNA is purified using Trizol reagent from Life Technologies (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.), essentially as recommended by the manufacturer. Poly A+ RNA (mRNA) is purified using magnetic oligo dT beads essentially as recommended by the manufacturer (Dynabeads, Dynal Corporation, Lake Success, N.Y. U.S.A.).

Construction of plant cDNA libraries is well-known in the art and a number of cloning strategies exist. A number of cDNA library construction kits are commercially available. The Superscript™ Plasmid System for cDNA synthesis and Plasmid Cloning (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.) is used, following the conditions suggested by the manufacturer.

The SOYMON005 cDNA library is generated from soybean cultivar Asgrow 3244 (Asgrow Seed Company, Des Moines, Iowa U.S.A.) hypocotyl axis tissue from seeds 6 hour post-imbibition. Seeds are planted at a depth of approximately 2 cm into 2–3 inch peat pots containing Metromix 350 medium. Trays are placed in an environmental chamber and grown at 12 hr daytime/12 hr nighttime cycles. The daytime temperature is approximately 29° C. and the nighttime temperature approximately 24° C. Soil is checked and watered daily to maintain even moisture conditions. Tissue is collected 6 hours after the start of imbibition. The 6 hours after imbibition sample is collected over the course of approximately 2 hours starting at 6 hours post imbibition. At the 6 hours after imbibition stage, not all cotyledons have become fully hydrated and germination. Radicle protrusion has not occurred. The seedlings are washed in water to remove soil, then the hypocotyl axis is harvested and immediately frozen in liquid nitrogen. The harvested tissue is then stored at –80° C. until RNA preparation. The RNA is purified from the stored tissue and the cDNA library is constructed.

The stored RNA is purified using Trizol reagent from Life Technologies (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.), essentially as recommended by the manufacturer. Poly A+ RNA (mRNA) is purified using magnetic oligo dT beads essentially as recommended by the manufacturer (Dynabeads, Dynal Corporation, Lake Success, N.Y. U.S.A.).

Construction of plant cDNA libraries is well-known in the art and a number of cloning strategies exist. A number of cDNA library construction kits are commercially available. The Superscript™ Plasmid System for cDNA synthesis and Plasmid Cloning (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.) is used, following the conditions suggested by the manufacturer.

The SOYMON006 cDNA library is generated from soybean cultivar Asgrow 3244 (Asgrow Seed Company, Des Moines, Iowa U.S.A.) cotyledons from seeds 6 hour post-imbibition. Seeds are planted at a depth of approximately 2 cm into 2–3 inch peat pots containing Metromix 350 medium. Trays are placed in an environmental chamber and

grown at 12 hr daytime/12 hr nighttime cycles. The daytime temperature is approximately 29° C. and the nighttime temperature approximately 24° C. Soil is checked and watered daily to maintain even moisture conditions. Tissue is collected 6 hours after imbibition. The 6 hours after imbibition sample is collected over the course of approximately 2 hours starting at 6 hours post-imbibition. At the 6 hours after imbibition, not all cotyledons have become fully hydrated and germination. Radicle protrusion has not occurred. The seedlings are washed in water to remove soil, then the cotyledon is harvested and immediately frozen in liquid nitrogen. The harvested tissue is then stored at -80° C. until RNA preparation. The RNA is purified from the stored tissue and the cDNA library is constructed.

The stored RNA is purified using Trizol reagent from Life Technologies (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.), essentially as recommended by the manufacturer. Poly A+ RNA (mRNA) is purified using magnetic oligo dT beads essentially as recommended by the manufacturer (Dynaheads, Dynal Corporation, Lake Success, N.Y. U.S.A.).

Construction of plant cDNA libraries is well-known in the art and a number of cloning strategies exist. A number of cDNA library construction kits are commercially available. The Superscript™ Plasmid System for cDNA synthesis and Plasmid Cloning (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.) is used, following the conditions suggested by the manufacturer.

The SOYMON009 cDNA library is generated from soybean cultivar C1944 (USDA Soybean Germplasm Collection, Urbana, Ill. U.S.A.) pod and seed tissue harvested 15 days post-flowering. Pods from field grown plants are harvested 15 days post-flowering. The pods are picked from all over the plant, placed into 14 ml polystyrene tubes and immediately immersed in dry-ice. Approximately 3 g of pod tissue is harvested. The harvested tissue is then stored at -80° C. until RNA preparation. The RNA is purified from the stored tissue and the cDNA library is constructed.

The stored RNA is purified using Trizol reagent from Life Technologies (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.), essentially as recommended by the manufacturer. Poly A+ RNA (mRNA) is purified using magnetic oligo dT beads essentially as recommended by the manufacturer (Dynabeads, Dynal Corporation, Lake Success, N.Y. U.S.A.).

Construction of plant cDNA libraries is well-known in the art and a number of cloning strategies exist. A number of cDNA library construction kits are commercially available. The Superscript™ Plasmid System for cDNA synthesis and Plasmid Cloning (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.) is used, following the conditions suggested by the manufacturer.

The SOYMON018 cDNA is generated from soybean cultivar Asgrow 3244 (Asgrow Seed Company, Des Moines, Iowa U.S.A.) leaf tissue harvested from plants grown in a field in Jerseyville 45 and 55 days after flowering. Leaves from field grown plants are harvested 45 and 55 days after flowering from the fourth node. Approximately 27 g and 33 g of leaves are collected from the 45 and 55 days after flowering plants, placed into 14 ml polystyrene tubes and immediately immersed in dry ice. The harvested tissue is then stored at -80° C. until RNA preparation. Total RNA is prepared from the combination of equal amounts of leaf tissue from both time points and the cDNA library is constructed.

The stored RNA is purified using Trizol reagent from Life Technologies (Gibco BRL, Life Technologies, Gaithersburg,

Md. U.S.A.), essentially as recommended by the manufacturer. Poly A+ RNA (mRNA) is purified using magnetic oligo dT beads essentially as recommended by the manufacturer (Dynabeads, Dynal Corporation, Lake Success, N.Y. U.S.A.).

Construction of plant cDNA libraries is well-known in the art and a number of cloning strategies exist. A number of cDNA library construction kits are commercially available. The Superscript™ Plasmid System for cDNA synthesis and Plasmid Cloning (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.) is used, following the conditions suggested by the manufacturer.

The SOYMON019 cDNA library is generated from soybean cultivars Cristalina (USDA Soybean Germplasm Collection, Urbana, Ill. U.S.A.) and Fr108 (Monsoy, Brazil) (tropical germ plasma) root tissue. Roots are harvested from plants grown in an environmental chamber under 12 hr daytime/12 hr nighttime cycles. The daytime temperature is approximately 29° C. and the nighttime temperature approximately 24° C. Soil is checked and watered daily to maintain even moisture conditions. Approximately 50 g and 56 g of roots are harvested from each of the Cristalina and FT108 cultivars and immediately frozen in dry ice. The plants are uprooted and the roots quickly rinsed in a pail of water. The root tissue is then cut from the plants, placed immediately in 14 ml polystyrene tubes and immersed in dry-ice. The harvested tissue is then stored at -80° C. until RNA preparation. Total RNA is prepared from the combination of equal amounts of root tissue from each cultivar and the cDNA library is constructed.

The stored RNA is purified using Trizol reagent from Life Technologies (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.), essentially as recommended by the manufacturer. Poly A+ RNA (mRNA) is purified using magnetic oligo dT beads essentially as recommended by the manufacturer (Dynabeads, Dynal Corporation, Lake Success, N.Y. U.S.A.).

Construction of plant cDNA libraries is well-known in the art and a number of cloning strategies exist. A number of cDNA library construction kits are commercially available. The Superscript™ Plasmid System for cDNA synthesis and Plasmid Cloning (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.) is used, following the conditions suggested by the manufacturer.

The SOYMON020 cDNA is generated from soybean cultivar Asgrow 3244 (Asgrow Seed Company, Des Moines, Iowa U.S.A.) seeds harvested from plants grown in a field in Jerseyville 65 and 75 days post-flowering. The seed pods are picked from all over the plant and the seeds extracted from the pods. Approximately 14 g and 31 g of seeds are harvested from the respective seed pods and immediately frozen in dry ice. The harvested tissue is then stored at -80° C. until RNA preparation. Total RNA is prepared from the combination of equal numbers of seeds from 65 and 75 days after flowering and the cDNA library is constructed.

The stored RNA is purified using Trizol reagent from Life Technologies (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.), essentially as recommended by the manufacturer. Poly A+ RNA (mRNA) is purified using magnetic oligo dT beads essentially as recommended by the manufacturer (Dynabeads, Dynal Corporation, Lake Success, N.Y. U.S.A.).

Construction of plant cDNA libraries is well-known in the art and a number of cloning strategies exist. A number of cDNA library construction kits are commercially available. The Superscript™ Plasmid System for cDNA synthesis and Plasmid Cloning (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.) is used, following the conditions suggested by the manufacturer.

The SOYMON022 cDNA library is generated from soybean cultivar Asgrow 3244 (Asgrow Seed Company, Des Moines, Iowa U.S.A.) partially to fully opened flower tissue, which is harvested from plants grown in an environmental chamber. Seeds are planted in moist Metromix 350 medium at a depth of approximately 2 cm. Trays are placed in an environmental chamber set to a 12 h day/12 h night cycle, 29° C. daytime temperature, 24° C. night temperature and 70% relative humidity. Daytime light levels are measured at 450 μ Einsteins/m². Soil is checked and watered daily to maintain even moisture conditions. Flowers are removed from the plant at the pedicel. Flower buds showing petal color to fully open flowers are selected for collection. A total of 3 g of flower tissue is harvested and immediately frozen in dry ice. The harvested tissue is then stored at -80° C. until RNA preparation. Total RNA is prepared from a mixture of opened and partially opened flowers and the cDNA library is constructed.

The stored RNA is purified using Trizol reagent from Life Technologies (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.), essentially as recommended by the manufacturer. Poly A+ RNA (mRNA) is purified using magnetic oligo dT beads essentially as recommended by the manufacturer (Dynabeads, Dynal Corporation, Lake Success, N.Y. U.S.A.).

Construction of plant cDNA libraries is well-known in the art and a number of cloning strategies exist. A number of cDNA library construction kits are commercially available. The Superscript™ Plasmid System for cDNA synthesis and Plasmid Cloning (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.) is used, following the conditions suggested by the manufacturer.

The SOYMON023 cDNA library is generated from soybean genotype BW211S Null (Tohoku University, Morioka, Japan) seed tissue harvested from plants grown in a field in Jerseyville. After 15 and 40 days, pods are harvested from all over the plant and seeds are dissected out from the pods. Approximately, 0.7 g and 14.2 g of seeds are harvested from the plants at the 15 and 40 days after flowering timepoints. The seeds are placed into 14 ml polystyrene tubes and immersed in dry-ice. The tissue is then transferred to a -80° C. freezer for storage. The harvested tissue is then stored at -80° C. until RNA preparation. Total RNA is prepared from the combination of 0.5 g and 1.0 g of seeds from the 15 and 40 days after flowering timepoints and the cDNA library is constructed.

The stored RNA is purified using Trizol reagent from Life Technologies (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.), essentially as recommended by the manufacturer. Poly A+ RNA (mRNA) is purified using magnetic oligo dT beads essentially as recommended by the manufacturer (Dynabeads, Dynal Corporation, Lake Success, N.Y. U.S.A.).

Construction of plant cDNA libraries is well-known in the art and a number of cloning strategies exist. A number of cDNA library construction kits are commercially available. The Superscript™ Plasmid System for cDNA synthesis and Plasmid Cloning (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.) is used, following the conditions suggested by the manufacturer.

The SOYMON028 cDNA library is generated from soybean cultivar Asgrow 3244 (Asgrow Seed Company, Des Moines, Iowa U.S.A.) drought-stressed root tissue. Seeds are planted in moist Metromix 350 medium at a depth of approximately 2 cm in trays. The trays are placed in an environmental chamber set to a 12 h day/12 h night cycle, 26° C. daytime temperature, 21° C. night temperature and 70% relative humidity. Daytime light levels are measured at 300 μ Einsteins/m². Soil is checked and watered daily to maintain even moisture conditions. At the R3 stage of

development, water is withheld from half of the plant collection (drought stressed population). After 3 days, half of the plants from the drought stressed condition and half of the plants from the control population are harvested. After another 3 days (6 days post drought induction) the remaining plants are harvested. A total of 27 g and 40 g of root tissue is harvested from plants at two time points and immediately frozen in dry ice. The harvested tissue is then stored at -80° C. until RNA preparation. Total RNA is prepared from the combination of equal amounts of drought stressed root tissue from both time points and the cDNA library is constructed.

The stored RNA is purified using Trizol reagent from Life Technologies (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.), essentially as recommended by the manufacturer. Poly A+ RNA (mRNA) is purified using magnetic oligo dT beads essentially as recommended by the manufacturer (Dynabeads, Dynal Corporation, Lake Success, N.Y. U.S.A.).

Construction of plant cDNA libraries is well-known in the art and a number of cloning strategies exist. A number of cDNA library construction kits are commercially available. The Superscript™ Plasmid System for cDNA synthesis and Plasmid Cloning (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.) is used, following the conditions suggested by the manufacturer.

The SOYMON032 cDNA library is prepared from the Asgrow cultivar A4922 (Asgrow Seed Company, Des Moines, Iowa U.S.A.) rehydrated dry soybean seed meristem tissue. Surface sterilized seeds are germinated in liquid media for 24 hours. The seed axis is then excised from the barely germinating seed, placed on tissue culture media and incubated overnight at 20° C. in the dark. The supportive tissue is removed from the explant prior to harvest. Approximately 570 mg of tissue is harvested and frozen in liquid nitrogen. The harvested tissue is then stored at -80° C. until RNA preparation. The RNA is purified from the stored tissue and the cDNA library is constructed.

The stored RNA is purified using Trizol reagent from Life Technologies (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.), essentially as recommended by the manufacturer. Poly A+ RNA (mRNA) is purified using magnetic oligo dT beads essentially as recommended by the manufacturer (Dynabeads, Dynal Corporation, Lake Success, N.Y. U.S.A.).

Construction of plant cDNA libraries is well-known in the art and a number of cloning strategies exist. A number of cDNA library construction kits are commercially available. The Superscript™ Plasmid System for cDNA synthesis and Plasmid Cloning (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.) is used, following the conditions suggested by the manufacturer.

The SOYMON034 cDNA library is generated from soybean cultivar Asgrow 3244 (Asgrow Seed Company, Des Moines, Iowa U.S.A.) cold-shocked seedling tissue without cotyledons. Seeds are imbibed and germinated in vermiculite for 2 days under constant illumination (ca. 510 Lux). After 48 hours, the seedlings are transferred to a cold room set at 5° C. under constant illumination (ca. 560 Lux). After 30, 60 and 180 minutes seedlings are harvested and dissected. The seedlings after 2 days of imbibition are beginning to emerge from the vermiculite surface. The apical hooks are dark green in appearance. A portion of the seedling consisting of the root, hypocotyl and apical hook is frozen in liquid nitrogen and stored at -80° C. Total RNA is prepared from equal amounts of pooled tissue and the cDNA library is constructed.

The stored RNA is purified using Trizol reagent from Life Technologies (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.), essentially as recommended by the manufac-

turer. Poly A+ RNA (mRNA) is purified using magnetic oligo dT beads essentially as recommended by the manufacturer (Dynabeads, Dynal Corporation, Lake Success, N.Y. U.S.A.).

Construction of plant cDNA libraries is well-known in the art and a number of cloning strategies exist. A number of cDNA library construction kits are commercially available. The Superscript™ Plasmid System for cDNA synthesis and Plasmid Cloning (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.) is used, following the conditions suggested by the manufacturer.

The SOYMON037 cDNA library is generated from soybean cultivar A3244 (Asgrow Seed Company, Des Moines, Iowa U.S.A.) etiolated axis and radical tissue. Seeds are planted in moist vermiculite, wrapped and kept at room temperature in complete darkness until harvest. Etiolated axis and hypocotyl tissue is harvested at 2.3 and 4 days post-planting. Samples are frozen in liquid nitrogen upon harvesting and stored at -80° C. until RNA preparation. 1 gram of each sample (axis+hypocotyl at day 2.3 and 4) is pooled for RNA isolation. The RNA is purified from the pooled tissue and the cDNA library is constructed.

The stored RNA is purified using Trizol reagent from Life Technologies (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.), essentially as recommended by the manufacturer. Poly A+ RNA (mRNA) is purified using magnetic oligo dT beads essentially as recommended by the manufacturer (Dynabeads, Dynal Corporation, Lake Success, N.Y. U.S.A.).

Construction of plant cDNA libraries is well-known in the art and a number of cloning strategies exist. A number of cDNA library construction kits are commercially available. The Superscript™ Plasmid System for cDNA synthesis and Plasmid Cloning (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.) is used, following the conditions suggested by the manufacturer.

The cDNA library of the present invention designated LIB22, is prepared from *Arabidopsis thaliana* Columbia ecotype root tissue. Wild type *Arabidopsis thaliana* seeds are planted in commonly used planting pots and grown in an environmental chamber. After 5-6 weeks the plants are in the reproductive growth phase. Stems are bolting from the base of the plants. After 7 weeks, more stems and floral buds appear, and a few flowers are starting to open. Roots of 7-week old plants from pots are rinsed intensively with tap water to wash away dirt, and briefly blotted by paper towel to take away free water. The tissues are immediately frozen in liquid nitrogen and stored at -80° C. until total RNA extraction.

The stored RNA is purified using Trizol reagent from Life Technologies (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.), essentially as recommended by the manufacturer. Poly A+ RNA (mRNA) is purified using magnetic oligo dT beads essentially as recommended by the manufacturer (Dynabeads, Dynal Corporation, Lake Success, N.Y. U.S.A.).

Construction of plant cDNA libraries is well-known in the art and a number of cloning strategies exist. A number of cDNA library construction kits are commercially available. The Superscript™ Plasmid System for cDNA synthesis and Plasmid Cloning (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.) is used, following the conditions suggested by the manufacturer.

The cDNA library of the present intention designated LIB24, is prepared from *Arabidopsis thaliana*, Columbia ecotype, flower bud tissue. Wild type *Arabidopsis thaliana* seeds are planted in commonly used planting pots and grown in an environmental chamber. Flower buds are green and unopened and are harvested about seven weeks after planting. The tissue is immediately frozen in liquid nitrogen and stored at -80° C. until total RNA extraction.

The stored RNA is purified using Trizol reagent from Life Technologies (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.), essentially as recommended by the manufacturer. Poly A+ RNA (mRNA) is purified using magnetic oligo dT beads essentially as recommended by the manufacturer (Dynabeads, Dynal Corporation, Lake Success, N.Y. U.S.A.).

Construction of plant cDNA libraries is well-known in the art and a number of cloning strategies exist. A number of cDNA library construction kits are commercially available. The Superscript™ Plasmid System for cDNA synthesis and Plasmid Cloning (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.) is used, following the conditions suggested by the manufacturer.

The cDNA library of the present invention designated LIB25, is prepared from *Arabidopsis thaliana*, Columbia ecotype, open flower tissue. Wild type *Arabidopsis thaliana* seeds are planted in commonly used planting pots and grown in an environmental chamber. Flower are completely opened with all parts of floral structure observable, but no siliques are appearing, and are harvested about seven weeks after planting. The tissue was immediately frozen in liquid nitrogen and stored at -80° C. until total RNA extraction.

The stored RNA is purified using Trizol reagent from Life Technologies (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.), essentially as recommended by the manufacturer. Poly A+ RNA (mRNA) is purified using magnetic oligo dT beads essentially as recommended by the manufacturer (Dynabeads, Dynal Corporation, Lake Success, N.Y. U.S.A.).

Construction of plant cDNA libraries is well-known in the art and a number of cloning strategies exist. A number of cDNA library construction kits are commercially available. The Superscript™ Plasmid System for cDNA synthesis and Plasmid Cloning (Gibco BRL, Life Technologies, Gaithersburg, Md. U.S.A.) is used, following the conditions suggested by the manufacturer.

EXAMPLE 3

Detection of Changes in Sterol Metabolism

A labeled acetyl-CoA molecule, squalene molecule, or acetate are used in a variety of assays to detect changes in sterol production, secretion, localization, protein-binding, degradation, and trafficking known in the art. The example below illustrates.

Cells from transformed plants are cultured in an appropriate medium. Labeled acetate, preferably ¹⁴C-labeled, is added to a concentration of about 1 uCi/ml. After a period of growth, the cells are collected, the lipids extracted, and resolved by thin-layer chromatography or run over HPLC column using known methods. The levels of each sterol resolved can be compared to control cells fed the same labeled ¹⁴C acetate and the amount of ¹⁴C-labeled sterol for each determined from the resolved sterols.

REFERENCES

In addition to those references cited and incorporated by reference above, the below references are incorporated in their entirety. In addition, these references, as well as each of those cited in the Summary and Detailed Description above, can be relied upon to make and use aspects of the invention.

- Jiang, et al., A new family of yeast genes implicated in ergosterol synthesis is related to the human oxysterol-binding protein. *Yeast* 10: 341-53 (1994).
- Fang, et al., Kes1p shares homology with human oxysterol-binding protein and participates in a novel regulatory pathway for yeast Golgi-derived transport vesicle biogenesis. *EMBO J.* 15: 6447-59(1996).
- Crowley, et al., A mutation in a purported regulatory gene affects control of sterol uptake in *Saccharomyces cerevisiae*, *Journal of Bacteriology*, 180(16): 4177-83 (1998).
- Casper and Holt, Expression of the green fluorescent protein-encoding gene from a tobacco mosaic virus-based vector. *Gene*, 173: 69-73 (1996).

SEQUENCE LISTING

The patent contains a lengthy "Sequence Listing" section. A copy of the "Sequence Listing" is available in electronic form from the USPTO web site (<http://seqdata.uspto.gov/sequence.html?DocID=6723837B1>). An electronic copy of the "Sequence Listing" will also be available from the USPTO upon request and payment of the fee set forth in 37 CFR 1.19(b)(3).

We claim:

1. An isolated nucleic acid molecule that encodes a ¹⁵ protein comprising the amino acid sequence of SEQ ID NO: 622.
 2. The isolated nucleic acid molecule of claim 1, wherein the nucleic acid molecule comprises the nucleic acid sequence of SEQ ID NO: 1.
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